CONSTRUCTION AND MAINTENANCE

OF

RAILWAY ROADBED AND TRACK

Arranged and compiled from authoritative sources with an exhaustive description

OF

RAILWAY SURVEYS AND CONSTRUCTION

PROFUSELY ILLUSTRATED

BY

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CHICAGO
FREDERICK J. DRAKE & CO., PUBLISHERS
1908

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TO THE MEMORY OF HIS LAMENTED SON,

FREDERICK GEORGE PRIOR,

WHO HAD BEGUN A PROMISING CAREER IN THE

FIELD OF CIVIL ENGINEERING,

THIS BOOK IS AFFECTIONATELY DEDICATED

BY THE COMPILER AND EDITOR.

PREFACE.

In railway operation one of the most important subjects is the construction and maintenance of roadbed and track. The problems presented owing to the different conditions met are multiplex. The subject is too great to be exhausted in a single volume nor has the subject been exhausted in the many books by many men.

It is, however, believed that the experience and technical knowledge herein set forth may serve to help and stimulate those for whom it is primarily intended, and that it may, perhaps, supplement the experience and studies of more advanced students who have access to textbooks and who have specialized on the subject.

Originality has not been attempted. To the labors of others the writer is indebted, therefore all claim to authorship is disavowed, the humble office of compiler and editor being all he aspires to. Credit is given in the text to those to whom it is due, but if, inadvertently, the source is in some instances not given, he hopes his grateful acknowledgment will be accepted.

Much of the great mass of relevant matter necessarily had to be rearranged and rewritten, and while it is impossible to meet the exact needs of every reader, yet, imperfect as it is, it is hoped the work may find a welcome in the field of technical railway literature and prove intelligible, interesting and instructive.

THE COMPILER.

SECTION I.

RAILWAY CONSTRUCTION.

The First, Second and Third Steps.

In the extension of existing railway lines or the building of new ones it is necessary to know first of all what will be the best route to take to render the most effective and profitable service to the population to be reached. The character of the road required, the probable cost of construction, and the expense of maintenance and operation after constructed have all to be taken into consideration. To determine this, the country through which the proposed line is to be built must be examined by engineers. This examination called a reconnoissance, is made under the immediate direction of a railway civil engineer. It is not, however, intended to give an accurate survey of the country examined. It is, instead, a report embodying the main features of the region through which the route is proposed to be taken. It should be of an area rather than a line, including as wide a belt on each side of an air line between two fixed termini as there is any possibility of the line reaching. The chief things to be shown in the reconnoissance report being, first: an approximate location; second: the certainty of being able to mount up from a valley on a given grade and get over the summit of the divide; (a "divide" is known by engineers as a line separating the water-sheds of two adjacent systems of drainage or rivers); third: the possi-

bility of descending from that divide, and of crossing the summit of the next on a given grade; fourth: the different elevations of the divide passes that are available; and fifth: the probability of the cost of its construction being within certain fixed limits.

Varying conditions make possible different methods of making a reconnoissance. In regions which have been settled and which are well known government surveys have usually been made, and accurate surveys and maps of them may generally be obtained. With such a map the engineer can accurately find the location of any desired point, as such maps give, as a rule, the township and section lines and the subdivision of sections by farm fences. A scale of one inch to a mile is considered best for the engineer's purpose in using such a map, but, where no government survey has been made it becomes necessary to make a map or plat on a larger scale, preferably two inches to a mile in order to show clearly boundaries of farms and other properties.

Provided with the necessary working equipment, consisting usually of the following: an aneroid barometer, field and note books, drawing paper, drawing instruments, steel tape, two or more tin map cases, a field glass, a hand level, and a prismatic compass, the engineer sets out, traversing the country on foot for the most part, to locate the controlling points. The summit is the principal controlling point in mountainous locations, while in prairie, plateau or bench locations, commercial centers, stream crossings, and controlling elevations form the principal controlling points. If he has plats or maps they will furnish him with the distances and he will mark upon his map the location of section lines, boundaries of farm and other property, water courses, ravines, hills, highways, towns,

villages, etc. By the use of the aneroid barometer, along the summits of divides he will ascertain the low points or passes, the elevation of valleys, and will also give the elevations of spurs from the divides. (Spurs are ridges extending from a divide and separating the water-sheds of two branches of the same river.) The contours of the country must also be platted at difficult points when necessary. (Contour is shown by lines laid down on a map showing the location of points of the same elevation.) If, on the other hand, he has no maps or plats indicating distances, etc., he must secure the elevation and distance of the controlling points. This necessitates the use of a pedometer and an odometer, also a good watch in addition to the working instruments already mentioned. The problem of determining latitude and longitude having been already reduced to sections he will not require instruments for that purpose. To illustrate: having made the summit of one divide, his problem is to cross the next valley and reach the summit of the next divide, using the desired grade and curvature. Any errors of distance made from one divide to another will not affect those beyond.

Unless there be positive knowledge of insurmountable difficulties in the way, the most direct line should be first examined. But in case there be apparently insurmountable difficulties, and after the territory to the right or left has been examined, the short route should not be too quickly abandoned. Experience has demonstrated that routes have been sometimes avoided because they gave the impression of difficult and expensive construction, which in the light of subsequent developments it was shown would have been, after all, not only the most desirable, but also the cheapest location.

The engineer, following the example of nature, usually works along the line of least resistance and in so doing uses nature's forces to overcome difficulties. Herein lies the wisdom and skill of the engineer, who thereby avoids long tunnels, heavy fills, deep rock cuts, and expensive bridging. As he proceeds he makes calculations and notes showing the probable nature of the component parts of the material which would have to be dealt with in construction, whether earth, sand, gravel, loose rock, hardpan or solid rock, giving also the approximate percentages of each in different cuts, the probable quantities to be excavated; the opportunities for obtaining a supply of fuel at points along the route; the water supply; the geological formations; the timber which would be available for ties, piling, trestles, etc.; the amount of embankments and bridging necessary per mile; the character of the rainfall and what effect it might have upon operation and the possibilities for business.

These notes are valuable to the projectors and also afford a basis upon which to estimate the probable cost of construction, but in the nature of things, the examination being merely preliminary, the estimates given in the notes are only approximated.

A proper reconnoissance report conveys a graphic impression of the features of the region and route traversed, and contains the fundamental elements affecting operation and construction cost. The engineer should separate the routes reported upon into natural divisions of similar characteristics, giving distances, grades and controlling points of each. He should describe, classify and approximately estimate the material to be moved and other work to be performed, giving averages per mile and totals for each section, and furnish an approximate

estimate of the cost per mile and total cost of the completed railway. Small scale maps and profiles showing general features, elevations, and distribution of ruling grades should accompany such reports, whenever necessary.

After the reconnoissance has been made, and the report duly considered, the results of which will have assisted in determining the maximum grades and degrees of curvature most acceptable, the next step is that of making the preliminary survey.

If the line be an entirely new one it will most likely be made under the immediate direction of the chief engineer, but in the case of extensions of existing lines, the preliminary survey, or second step, is made by a locating engineer. The data and other particulars derived from the reconnoissance are put into his hands, armed with which he takes the field with a corps of assistants. These are organized into parties, the character and size of each party being to a greater or lesser degree determined by such considerations as the character of the country, whether or not there are reasons for great haste, and also the amount it is expected shall be expended. The organization of the parties is generally as follows:

(1) A Transit party.
(2) A Level party.
(3) A Topographical party.
(4) A Draughting party.
(5) A Commissary or Camp.

The transit man is generally in full charge of the work during the absence of the locating engineer. He is assisted usually by a head flagman or chainman, a rear chainman, an axeman or stake driver and a rear flagman.

The transit man is held responsible for the accuracy of all measurements taken.

The leveling party consists of a leveler and a rodman. The topographical party is a rather uncertain quantity in its composition or make-up. Sometimes it consists of a level man, a rodman, and an axeman, while at others it is represented only by notes made by the locating engineer and transitman. The draughting party is represented by one or more draughtsmen to make the necessary drawings and record the results of the progress as made and to make such maps as are needed in the work.

The commissary and camp party is a very important adjunct to the whole when the route lies through wild and sparsely settled regions, when it is important to make every provision possible to house and feed the forces engaged in the work and otherwise provide for their health and comfort. Not to make such provisions might result in serious delays through lack of subsistence or sickness, whereas to make as adequate provision as possible ensures a better degree of efficiency in the work performed. In well settled portions of the country the commissary and camp is not, of course, so requisite.

The locating engineer must, to successfully make the preliminary survey, be resourceful. He must be ready to adopt old methods to new conditions. Must know how to devise new methods to meet conditions which may not be new to other engineers, but are to him. Difficulties, problems, and obstacles present themselves continually, particularly in getting through rocky canons, marshy plains too soft for men to walk over, yet without water enough to float a boat, heavily timbered country with thick growth of underbrush, and scores of other things

all involve obstacles that at times overtax the resources of the engineer, but all must be overcome.

The preliminary survey should be thorough, and all improvements in the line and grade which appear possible should be tried so that when the third step in construction is taken the work may proceed with but few if any changes, and with rapidity.

The locating engineer is not only required to be skillful in his profession, but he must likewise be tactful. He is called upon frequently to use tact in dealing with people along the line of the survey, and in doing this, he must consider their prejudices, their local history and who among them are the leaders in forming public opinion; all this he should make notes of for possible future use; and in handling the men in the field parties in his charge he must be a born general, able to get the maximum amount of work done with the least possible amount of friction between the members.

The third step in construction is known as the location. The particulars in detail of all the available routes having been furnished first, by the report of the preliminary examination, called the reconnoissance, and second, by the results of the more exact preliminary survey; the selection of a definite route is next made. Of course, in arriving at a conclusion there will have been taken into consideration the various grades and curves possible; the engineering obstacles to be overcome; and as the theory of location is said to be summed up in these words: "Engineering is the art of making a dollar earn the most interest," the probable cost of operation and maintenance as well as that of construction will have been also carefully considered.

The organization of the parties to undertake the work

of final location differs but little from those engaged in making the preliminary survey.

The transit party will, however, now lay out the spirals, curves, etc., in detail (unless the work of locating was carried on at the time of making the preliminary survey, which sometimes is done). The duties of each party are about the same as described in making the second step, although the notes made by the topographer will be more full and exact and will not cover as great an area to the right and left as before; while, of course, the draughtsman will pay greater attention to detail and will finish his profiles and maps with more exactness and care.

DETAILS OF CONSTRUCTION.

Having briefly outlined in general terms of an introductory character the first, second and third steps in railway construction, the details and technical, expert, particulars and instructions, covering the work of construction, from the commencement of the first step to the completed road, may be best described by Mr. J. R. Stephens, a Railway civil engineer of long experience and a writer of repute, who says:

The reconnoissance should not be a line, but of an area, including as wide a belt on each side of an air-line between two fixed termini as there is any possibility of the line reaching. Prepossessions in favor of the most obvious routes ought to be set aside, especially those *lying close to highways* or the open districts.

Lines hard to traverse on foot, seem worse than they really are. Raggedness of detail, sharp rock points, steep bluffs and the like, extending over short distances exert

an undue influence when compared with long rolling slopes stretching for longer distances.

Routes are compared on the bases of total cost and operating value. Short sections of expensive work may, when averaged with the balance of a line, show a less cost per mile than another line of more uniform character.

The reconnoissance report should show the main features of the region traversed and contain the elements affecting operation and construction cost. The Engineer should separate the routes reported upon, into natural divisions; giving the distances, grades, and controlling points of each. He should describe and approximately classify and estimate the work to be done, giving averages per mile and totals for each section, and furnish an approximate estimate of the cost per mile and total cost of the completed railway.

The Engineer should keep a diary in which to enter all items of interest pertaining to the work.

From this, reports with sketches, profiles, etc., are made up and transmitted to the Chief Engineer each week.

A complete sketch map of the water courses and divides should be made as the reconnoissance proceeds—sufficiently exact to enable the Engineer to state positively whether and where the water of each stream crossed joins another, until both have passed off the limits of the *area* under examination. On this map the water sheds should be outlined with the location of all low divides.

Engineers ought to make the preliminary reconnoissance in person, using prismatic compass, odometer, pedometer, hand level and "Aneroid," as they may be required. When there are several routes this process will usually eliminate one or more of them from further con-

sideration. The first step is to obtain the best available maps of the country, such as those of the Geological Survey.

Where reliance is to be placed on barometric elevations, two well adjusted barometers should be used, one of which is to be kept at a fixed elevation at some convenient point; while the other is carried over the route. Observations of the fixed barometer should be made every half hour, and from them a daily curve platted. Observations with the line barometer should always be timed so that its readings may be platted on the daily curve sheet and the true difference of elevation thus obtained.

The *exploration line* should be run as rapidly as possible over the entire route In case of very long lines, circumstances may make it necessary to carry on and complete the surveys by sections, but this should, if possible, be avoided.

The purpose of the first line should be merely to get the general idea of the topography of the country, and especially of the gradients, and it should be run over all feasible routes. No attempt to study the location in detail should be made, but the most favorable ground in the vicinity should be selected.

A *full-scale* profile of the ordinary form may sometimes be necessary, but not usually for the entire distance.

A small scale profile, 4000 feet to the inch horizontal scale and 100 or 200 feet per inch vertical scale, (depending on the nature of the line) and showing elevations, ruling grades and general features should in all cases be made.

Small scale maps should accompany and explain the profile. As a rule, for all surveys, maps should not be made

to a larger scale than will well show the smallest details of frequent occurrence.

Occasional details may be shown enlarged on one side of the same map. It is not necessary to increase the scale expressly for them. Condensed maps and profiles enable one to get a better grasp of the problem in hand.

Exploration lines, especially when in timber, should be run with compass bearings; in open country stadia readings may be used to obtain both distance and elevation. This facilitates the immediate determination of controlling points within the area studied.

In stadia lines, as elevations by vertical angles are of the greatest importance, the Engineer should see that he is provided with a good transit, having a full vertical circle, and reversion bubble on telescope, so that all vertical angles may be checked by reversing.

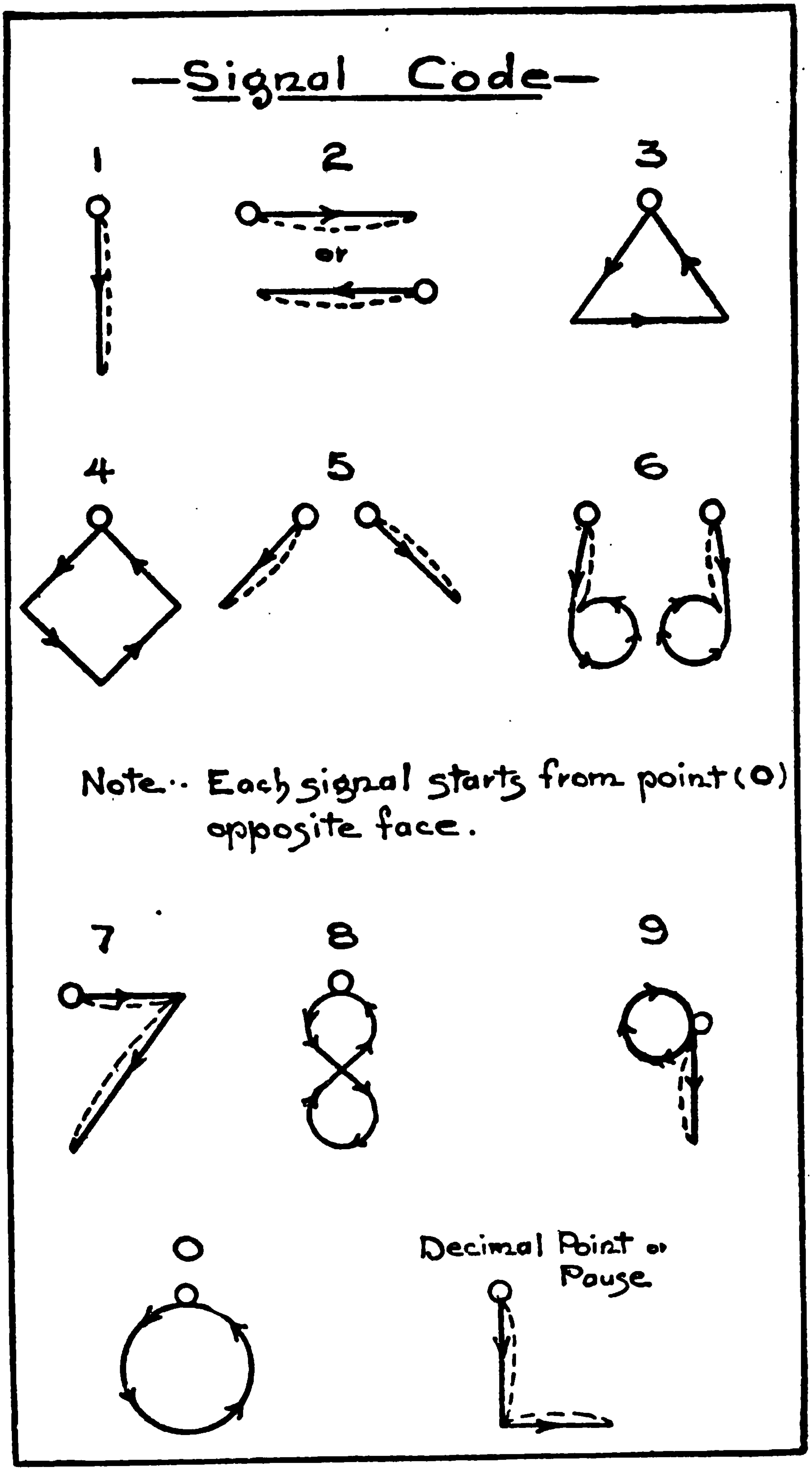
Stadia tables and a 10-inch stadia slide rule are great conveniences.

All points occupied by the transit should be marked by hubs, which are necessary as reference points in future work. Whenever possible locate hubs where they may be readily found and at the same time are not apt to be disturbed, as for instance, close to fences, walls or trees, which latter should be blazed.

As general signals for moving the rodman into position, etc., in stadia work, the following may be used. (See diagrams.) They depend on two principles:

First. The signal for each figure starts from a point directly in front of the eyes and returns to same point to complete the signal.

Second. It is a matter of indifference with which hand the signal is made or whether the motion is direct or reverse.


—Signal Code—
1
2
or
3
4
5
6
Note.. Each signal starts from point (O) opposite face.
7
8
9
0
Decimal Point or Pause

For considerable distances a handkerchief may be held in the hand while signalling.

Each number should represent a pre-arranged phrase as in telegraph codes: Thus, 47 might mean:—"Hold on creast immediately behind you"—39—"Hold in bottom of creek"—24—"Hold on fence corner," etc.

In the diagrams the mark "O" indicates the initial point, and the dotted lines, the return trip to the starting point.

These signals are also useful for setting the target and recording the exact elevation of same in the usual method of levelling with Philadelphia Rod.

LINE SURVEYS.

Before the survey of any route is commenced the Locating Engineer receives instructions from the Chief Engineer as to the gradients and curves to be used on the survey, the bases for comparing the desirability and equating the operating value of different lines between common points and such other instructions as may be needed for his guidance.

Engineers have immediate charge of surveying parties and are expected to see that their parties are well supplied with instruments, tents, stationery, provisions, and all the tools needed to the proper and vigorous prosecution of their work. (See list in appendix.)

First project the route of best grade and alignment, working back to the final and most economical route, with due consideration for side lines which avoid heavy work for short distances and which may serve temporary purposes.

But all surveys should be made with regard to futur

permanent construction and every effort used to reduce the amount of temporary construction, which may be required, to the least limits.

Note that the really vital and dangerous errors of location, such as the selection of the general route, the system of gradients, the passing by of local towns, etc., are usually committed in running preliminary lines.

Every effort must be made to maintain the lowest practicable and economical rate of grade over the entire engine district.

When sections of high grade are unavoidable try to concentrate the "rise and fall" into short sections for operation by assistant power.

Adjust the ruling grades of each engine district with reference to those of the adjoining district, and to conditions of local traffic, and thus avoid "breaking and making up of trains."

On sections, to be worked by assistant power, produce the maximum and the minimum ruling grades to an intersection if possible.

Note: To find the gross tons behind tender that a locomotive will haul on a given grade: Multiply the weight on drivers in tons by the per cent adhesion (usually 22), and divide by the rate of grade plus four-tenths. From the quotient deduct the total weight of engine and tender.

Thus, given a locomotive with total weight (engine and tender) 100 tons, weight on drivers 60 tons. What load can be hauled behind the tender on 0.6 grade with the adhesion 22% of the weight on drivers?

$60 \times 22 = 1320 \div (0.6 + 0.4) = 1320 - 100 = 1220$ tons, ans.

Engineers should keep a diary in which they will enter very evening a record of the day's work. This diary

should contain everything of value noted during the day. It should be turned in, with the balance of the notes, when the survey is completed. It will form the basis of the weekly reports, which Engineers furnish, stating progress and giving all other items of general interest pertaining to their work, with reasons for running the various lines, etc., particularly noting traffic possibilities.

These reports should be illustrated with small scale maps, sketches, and condensed profiles, etc. They should show number of days of delay or time lost with reason for same. They should be sent promptly to the Chief Engineer every week.

The Engineer should note in his diary, and on the map, objects near the line that should be avoided; and will give his opinion in the reports as to how his line may be changed, shortened or otherwise improved, noting particularly the physical differences between the two sides of the same valley and their effect on the cost of construction and operation. And make full comparisons of the relative merits of the different lines.

PRELIMINARY SURVEY.

Preliminary surveys should be run with care and must be made to approximate closely to the line which would be adopted on final location, this more particularly when estimates are to be based upon them.

The purpose of the preliminary is to serve as a base for the topography and the located line, and it should follow closely the ground where the location will lie, using any convenient angles for this purpose.

It is sometimes advisable to run in curves at critical places. This may be quickly done off-hand by measuring

the intersection angle with a prismatic compass. Then the external secant and tangent are determined by pacing. From this the degree and point of curve are determined usually from a table of functions of a 1 degree curve.

The preliminary, to avoid clearing, etc., may be a compass line, if any time is thereby saved for more important matters, remembering, however, that when the level limits the rate of progress, the time the transit has to spare should be occupied in carefully fitting the preliminary to the ground.

Whenever the country becomes quite rough and difficult, and especially where a grade line is to be fitted to the ground, the preliminary line should from the beginning be divided into two by running a first and second preliminary.

Note:—The use of stadia wires in running grade lines. Thus when telescope bubble is level, upper and lower wires give plus five-tenths and minus five-tenths grades. Then, after first noting distant objects covered by horizontal wires and moving telescope vertically until one wire covers an object previously covered by another, 1% and 1.5% grades may be obtained and intermediate grades by estimation.

LOCATION.

The first location should be made approximately correct as it goes along, by backing up, to correct the most serious and evident defects. Minor changes and modifications should be noted but not re-run as the first location advances. After completing the first line and taking necessary cross-sections and topography the party should, if so instructed by the Chief Engineer, re-run the first line.

Velocity grades requiring speeds in excess of twenty-five miles per hour must not be used, nor should such grades be laid out for speeds in excess of that obtainable under ordinary working conditions.

Exercise extreme care in fixing the locations for stations, water-tanks, coaling plants and crossings, and in adjusting grades for same, to reduce the cost and disadvantages of train stops to the minimum.

Train stops on or near the foot of grades should always be avoided if possible, and when not avoidable for any reason, the rate of grade should be compensated to facilitate the starting of trains, at least four feet vertical.

Note for record the kind and quality of material to be moved, observing quarries, wells or other indications for the purpose; the timber and rock in the country traversed, with a view to their use in construction.

The usual classification of grading will be: Common Excavation, Solid Rock, Solid Rock Borrow and Loose Rock. If cemented gravel or soft rock in place or other distinctive material exists in considerable quantities, the fact must be reported to the Chief Engineer in order that it may have proper classification assigned to it.

Trestling unless required for water ways, should not be considered unless the cost of embankments will exceed both the first cost of such bridges and the subsequent cost of filling the same by train or otherwise.

Note that stream diversions, even when of considerable magnitude, usually prove much cheaper both in first cost and in maintenance than bridging, particularly when the excavated material is used in embankments.

The maximum gradient belongs to tangents only, and the rate of ascent upon all curves must be sufficiently less than the maximum to compensate for curvature.

Curves on maximum gradients having much curvature must be compensated at a rate of .04 feet per degree. On grade lines having but little curvature .05 feet per degree may be used.

In compensating for curvature it is usually convenient to multiply the total angle of the curve in degrees by the rate of compensation per degree, and then lighten the grade by this product between the full or half stations, within which the curve lies, regardless of the exact position of the point of curvature, or the point of tangency.

A grade of at least 0.2 per station is required for drainage cuts.

A rate of curvature less than 1 degree per 100 feet, should not be used, except in cases where the intersection angle is less than three degrees. As curves less than 300 feet in length are objectionable, a rate of curvature should be used to give that length. Curves lighter than 1 degree should not be made longer than 300 feet.

DRAINAGE.

Locating Engineers should give special attention to the determination of the necessary length of bridges and size of culverts, and should keep a note book in which are entered an estimate of the extent and a general description of the character of the area drained by each water-way; cross-sections of stream at flood height, and any other items of importance bearing upon the question of drainage. These notes should be full and explicit, and should give the local names of creeks and small streams, as well as the names of rivers, and should refer to the number of the nearest survey stake in describing all water-ways.

On all located lines, detail profiles on plate "A" profile

paper, scale 20 feet to an inch, should be made of ravine sections, where bridges are required. This should show the center line for a greater distance than the length of the proposed bridge, and also, a parallel line on each side 25 feet from center line. Also the high water mark, surface indications of rock, as well as grade line with elevations of stations and rate.

Thorough drainage is a maxim to be impressed on the mind, and Engineers should be aware of being misled in so called "rainless districts."

A tidal estuary may generally be narrowed considerably from the extreme water lines if stone revetments are used to protect the banks from wash. In sections where the current is sluggish, it is usually safe to encroach a little on the general width of the stream, but in rapid streams among the hills, the width that the stream has cut for itself through the soil should not be lessened, but in ravines carrying mountain torrents the openings must be left much larger than the ordinary appearance of the banks of the stream would seem to make necessary.

Culverts and water-ways of perishable material should have ample allowance for future permanent construction.

DRAINAGE AREAS.

Drainage Areas should be measured while the location survey is in progress, for the purpose of determining the size of bridge openings.

The areas of streams more than 12 or 15 miles long may usually be taken from maps; areas for smaller streams, however, should be taken by the topographer or a competent assistant. This may be done most rapidly and with sufficient accuracy by stadia methods (see Explora-

tion Surveys) or where the country has been surveyed in the rectangular system, and where the land lines are marked on the ground, by sketching the divides between water-sheds on a map, and measuring the included areas.

For this purpose the larger squares of a topography book are numbered to correspond to the sections of a township, the smaller squares representing one-hundredths of a square mile.

The located line is then plotted on the map and the divides and water-ways as well as the 25 station points marked on this line.

Starting from the summits on the located line, the ridges are sketched orienting the map by a pocket compass. Distances are paced and the position of the ridge line corrected at each land line crossed by pacing to the nearest land corner.

The drainage areas in square miles and hundredths are found by counting the squares included in each drainage area.

Where the drainage areas are large, the work may be done much more rapidly on horse-back, the distances being measured by counting the paces of the saddle animal. For this purpose a tally-register is found convenient.

In addition to sketching the ridge lines the Topographer should take notes of the character of slopes and surface of watersheds, from which the Locating Engineer may determine how to modify the tabular areas of waterways in each particular case.

All lines sketched in the field should be traced in ink and a table made in the back of the book giving stations of water-ways with those of the divides between them and the corresponding drainage areas. Drainage areas should also be marked on the profile.

The Topographer should make large scale sketches of all streams near the crossings, from which the proper position of bridges as well as changes of channel may be determined. He should also note where waterways can be consolidated.

WATER SUPPLY.

Locating Engineers should be particular to note suitable and well situated sources of water supply for tanks, etc.

In case of doubt as to the suitability of the water for locomotives, samples should be sent, properly sealed, to the Chief Engineer for analysis.

GENERAL.

If the beginning of a line is at a junction with any constructed line or railroad, full notes of the connection must be taken; and such measurement from depots, switches or other important land marks as will give full identification. The initial point of all branches will be the junction with the constructed line, and should be referred to the nearest head block or other fixed point in the vicinity.

In running lines through agricultural lands care should be taken to avoid destruction of crops, orchards or other property. Where such property is destroyed, a reasonable and proper damage should be paid for the same.

Stations are usually uniformly one hundred feet long each, and numbered consecutively. It is not necessary to set stakes at each station in all cases on preliminary lines; this is left to the discretion of the chief of the party. Mark stakes on alternative lines with distinguishing letters. A. B. C., reserve L. M. N., for located lines.

Mark points of curvature "P. C." Point of tangency "P. T." on stakes at the beginning and end of all curves. Mark stakes "P. C." with the degree and direction of the curve.

Intersection points on location are unnecessary when much time is required to put them in. Their real use is for connecting lines run in opposite directions.

On location assume that there will be an off-set of 3 feet inwards for maximum curve to allow for spirals, lighten curves accordingly, and run lines at critical places with this in view.

Put in good solid hubs with witness stakes at all transit points, and stakes at plusses that come under fences. A record of these plusses should be kept in the transit book. *This is important.*

Always begin long grade lines at the summit, and work down. For such service carry a slip of profile paper, say six inches wide and two feet long. Rule the proposed grade line on it, assume a summit cut, mark the stations, and start down. When at fault, the elevation can be spotted on the profile, which will show at a glance the relation to grade.

All courses of the line, both true and magnetic, should be given, and, for the former, an observation must be taken upon starting the survey and the true course recorded in the field book as the work progresses. An additional observation should be taken for the correction of meridianal convergency whenever the extent of the survey shall attain a departure of one-half degree of longitude. See the following two examples, notes and remarks:

TO DETERMINE THE MERIDIAN FROM ALT.—AZIMUTH OBSERVATION OF SUN.

Example 1.

(L) Latitude	42° 44′	Arith. complement log. cos.	0.133996
(A) Altitude	30° 13′	" " " "	0.063422
(P) Polar Distance	85° 29′		
	2)157° 86′		
S.............	79° 13′	log. cos.	9.272064
P-S...........	6° 16′	log. cos.	9.997397
			2)19.466879
			9.733440
		Which is log. cos. of 57° 14′	
		2	
		Azimuth 114° 28′	

which is the required horizontal angle at the instrument between the sun and the true north point.

Example 2.

(L) Latitude	42° 16½′	Arith. complement log. cos.	0.130819
(A) Altitude	37° 16½′	" " " "	0.099229
(P) Polar Distance	71° 47′		
	2)150° 80′		
S............	75° 40′	log. cos.	9.393685
S-P..........	3° 53′	log. cos.	9.999002
			2)19.622735
			9.811367
		Which is log. cos. of 49° 38′	
		2	
		Azimuth 99° 16′	

Note:—The polar distance is obtained by adding the sun's apparent declination as obtained from the Nautical

Almanac to 90° when the sun is south of the Equator, and subtracting the same when the sun is north of the Equator.

The latitude is similarly computed from an altitude observation of the sun at noon, corrected for refraction, or from maps.

The altitude (A) is also to be corrected for refraction.

The refraction equals the natural contangent of the altitude expressed in minutes. Thus for an observed angle of elevation of 33° 41′ the natural contangent being 1.5, the corrected altitude would be $33° 41'—1.5'=33° 39\frac{1}{2}'$.

The correction for refraction must always be subtracted from the observed altitude.

In taking out the arithmetical complement of the log. cosine subtract from 9.999999, beginning at the left and passing to the right.

When taking the observation for Azimuth the sun should be at least two hours from the meridian.

Note that the cosines are used throughout and that the word L. A. P. S. gives the order of procedure.

Remarks:—This method cannot be used when the sun is near the meridian. The necessary observation may be taken by fastening a card with thumb tack on the end of a long lead pencil, so that the plane of the card is at right angles to the axis of the pencil. The pencil is then fastened to the eye end of telescope by rubber bands around the tube, so that a sharp image of sun and cross wires can be projected on card.

The card should be colored to prevent dazzling the eye. An instrument with telescope level and vertical arc is essential. At least two observations should be taken and calculated as a check, and if sun's circumference be ob-

served an observation should also be taken on center to make sure that the corrections for sun's semi-diameter are properly applied.

It is necessary to re-adjust the focusing of the cross wires in order to make them show on the card and with an inverting eye-piece the aperture of the objective should be cut down to the fraction of an inch.

To illuminate the cross wires when observing the North Star wrap a piece of tracing cloth around the object end of the telescope, so that one half the object glass is loosely covered. The cloth may be secured by a rubber band. Then illuminate with lantern from one side. A good night foresight may be a suitable "X" marked on tracing cloth tacked over a box with a candle or lantern inside the box.

Check all change angles by reversing and with needle reading.

In order to secure accuracy of alignment upon the straight lines, the transitman must take double sights when establishing instrument points, reversing the telescope to correct errors of adjustment.

In running curves, a tangential angle of fifteen degrees from one point should rarely be exceeded; twenty degrees is to be regarded as a maximum.

LEVELS.

Levels on preliminary lines, where speed is an object, and the progress of the level limits that of the party, may be run with the self-reading rod without target. For checks on turning points the rodman will invert the rod. The sum of the direct and reverse readings will be equal to the length of the rod.

Levels on located lines will generally be run with the Philadelphia Rod with target, and the rodman must carry a level book in which to record all turning points and benches, calculating the elevation of same and also each height of instrument; checking with the leveler each time they pass each other.

The level rod on turning points and benches should be read to hundredths. On ordinary line points to the nearest tenth.

On all turning points and benches, the greatest care must be taken to get the vertical rod reading by using a rod level, by balancing the rod, or by waving it when there is a wind.

Always establish a substantial and permanent bench at the initial point of surveys, and at 2,000 feet intervals along the line where they will be protected. Until a line is put under construction it is unnecessary to go off the center line to establish bench marks, if a good point can be found close to the center line. For this, a good hub on the center line, close to a fence or wall may be used. Use the sea level datum, and if one has to be assumed, ascertain its relation with the standard datum at the first opportunity and make proper note of the same.

The elevation of benches must be plainly marked upon a "blazed" spot upon trees, or upon a stout guard stake driven a foot from the bench mark.

All bench marks must be fully described in the level notes and both elevation and description noted on profile as they are established, and at the back of each level book a few blank pages should be left, on which should be entered a list of the benches upon that part of the line covered by the book, and a table of the alignment of the survey within the same limit.

The Leveler will note the surface elevations, the depths and the flood heights of all considerable streams crossed, take elevations in the beds of small streams, and, at suitable intervals, the high water marks, of streams parallel to the line.

He will keep a note of occasional turning-pegs, describing them with reference to the nearest stake, so that the levels may be taken up speedily in case of a revision of the line.

All level notes must be checked at the end of each day's work by adding the back-sights and foresights, and ascertaining the difference. Doubtful sections must be re-run.

Six hundred feet each way should be regarded as the maximum sweep of the level.

The Leveler should use a hand level to peg into narrow hollows, or over heights which can be turned with the instrument. He must record his work and make up his profile daily.

TOPOGRAPHY.

On preliminary wherever helpful to location, and on location wherever helpful to revision, topography must be carefully taken.

Since the amount of topography actually needed and used is small, no attempt should be made to cover the whole map with *accurate* topography. On the other hand, accurate contour lines for a reasonable distance on each side of a line are a great aid in projecting location, and, at critical places must not be omitted. Enough sketched topography should be used to show that no other and better alignment might have been adopted.

The topography should be carefully taken by actual measurements to important points; and must correctly

show by contour lines where the surface of the ground is intersected by horizontal planes at each even 10 feet of height; taken on the datum of the survey. Every fifth contour line should be heavy and have its elevation marked upon it. These contours need be shown only on long grade lines or at places where the surface is considerably broken or sloped. On grade lines, the grade contour, or line where the plane of grade intersects the surface of the ground should be dotted in.

Topography is neither to be used as a safe-guard against the larger errors of location, nor for giving the last degree of perfection to details of alignment. The finishing work must be done on the ground.

LAND LINES.

Connect with all township or sub-division lines of land surveys in the vicinity of the line of the railroad survey. These measurements should include the angle made by the railroad line with each township, section or other land line; the station of the railroad survey at which the line intersects any land line; and the distance along the land line to the nearest section or quarter corner, or other fixed point. A correct plat properly oriented must be drawn in the topography book, showing plainly all the above information.

When the line is located through villages or towns, all measurements necessary to tie the center line to the plat should be taken. Tracings of the town plats should be secured as contained in the Registrar's Office, with the dates and certificates contained in the original, and copies sent to the office of the Chief Engineer.

All the above land connections should be made complete on final lines. On preliminaries as much should be taken as can conveniently be obtained.

MAPS.

Every map and tracing should have a title, giving the corporate name of the Railroad Company, the name and date of the survey, and the names of the Locating Engineer, Transitman, Topographer and Draftsman.

The scale should be distinctly marked, and also the true and magnetic meridians. When the former is not otherwise known, draw it from the magnetic variation.

Maps and profiles should follow the same general direction, South and West to the left and North and East to the right.

Preliminary maps should, in general, be on a scale of 2,000 feet per inch. General maps comparing preliminaries may be drawn to a scale of 4,000 feet per inch, and should be accompanied by a condensed profile on plate "A" paper, horizontal scale 4,000 feet per inch and vertical 100 or 200 feet per inch, (depending on the nature of the line).

Location maps should be drawn from 600 to 200 feet per inch (usually 400), depending on the nature of the line.

To avoid cumulative errors in platting, all angles must be laid off from some standard bearing, using the calculated course for this purpose. This can best be done by laying off any convenient bearing in the general direction of the survey and transferring all angles turned from this line by parallel rules or triangles, to the last point scaled. This will, on located lines, require all tangents to be cal-

culated from intersection to intersection. The use of tables of latitudes and departures to single minutes is of great assistance.

On sloping ground, on grade lines, and at all critical places even ten foot contours, based on the profile datum, must be shown. Every full fifty foot contour must be drawn heavier. At suitable intervals leave short spaces in which mark the contour elevation.

On grade lines the grade contour must be shown.

Draw enough general topography to give a true conception of the character of the adjacent ground. And the position and direction of all water courses near the line should be shown.

MAPS MUST SHOW

The Station and plus of every "P. C.," "P. C. C." and "P. T." Central angles of curves and true bearings of tangents. On preliminaries give all angle points.

The mile posts from the initial point and the full stations at suitable intervals.

The position and name of any village or farm house near the line, and the course and direction with arrows of all streams.

Property lines, names of owners, section lines, political boundaries and roads.

On location maps the width of right of way required with the extra amount necessary for stations, side-tracks, Y's, borrow pits, waste banks, etc.

Details of junctions, stations, etc., should be shown on a larger scale and if convenient may be put to one side on the general map.

The use of colored inks is discouraged. It should be

the object of the Draftsman to make his map clear without this aid; and so that it will not lose any of its utility by being traced and blue printed.

Tracings of maps should be sent to the office of the Chief Engineer, as the same are completed. They should invariably be made on the unglazed side of the paper.

All maps, plats and profiles should have about nine inches clear at each end, so that handling will not make the marking indistinct.

PROFILES.

Profiles may be made in ordinary country on a sheet one-third of the width of ordinary profile paper. In rough country it will be advisable to use the width of one-half the ordinary profile paper.

Any profile made upon transparent profile paper or profile muslin should, if it is to be made within the width of one-third of a sheet, begin in the middle third of the sheet; the next part upon the lower third and the paper then reversed and the remaining third constructed from the other edge. This will facilitate its reproduction, and the prints can be separated by scissors and then joined at the ends. In this case, care should be taken that the profile is so placed on the one-third sheets, that it will match when thus cut and joined.

Breaking is sometimes facilitated by ruling in the intermediate 25 foot elevation lines and using them as 50 foot lines.

The line will be divided into sections, averaging about one mile in length, and breaking at the nearest full station. Each section should be separately estimated.

This will not prevent the removal of material required

for the roadbed or structures from one section to another, whenever in the opinion of the Engineer this may be expedient.

Profiles should break where practicable, in the same sections as the maps, and have a corresponding title.

They should be made to read in the same direction with the maps, West and South being at the left hand, and North and East at the right hand.

The Engineer should try to put all information in regard to the line, such as camping places, springs, water supply for tanks, etc., on the profile as it is then in a convenient and accessible form.

When right of way is to be obtained the land lines and boundaries of right of way should be marked on the profile, with reference to the center line, assuming the latter to be a continuous tangent—Scales 400 feet per inch longitudinal and 200 feet per inch transverse.

Profiles must show, as far as possible:

Near the top of the profile the "P. S.," "P. C.," "P. C. C.," and "P. T.;" angle points, all angles between consecutive tangents with direction right or left, degree of curve and true bearings of tangents.

The *Surface* of the ground, grade line, rate of grade, elevation of every angle in the grade in figures directly below it.

The location, description and elevation of all benches.

The position of mile posts, and the elevation of every 100 feet line at frequent intervals.

If the profile is made to an assumed datum, a note to that effect adding "To reduce to true elevation above the sea add —— feet." "To reduce to any contiguous datum add —— feet;" leaving out the figures if not known, but ALWAYS adding note.

The elevation of both high and low water for streams crossed; and, at intervals, of all streams with which the line runs closely parallel.

Distinguishing marks in all cuts other than earth.

The estimated and actual structures, including bridges, buildings, culverts, etc., required at all points where they are known, with notations of all proposed special work, such as changing channels of water courses, protection of embankments, etc.

The estimated or actual quantity in each cut or fill; with the yards and direction of overhaul, with a summary by sections as follows:

Right of way..................	Acres.	
Clearing	"	
Grubbing	"	
Common Exc.................	Yds.	
Loose Rock....................	"	
Solid Rock.....................	"	
" " Borrow...........	"	
Embankment borrowed........	"	
Rip rap	"	
Trestle bridging, pile and frame.	Lin. ft.	
Culverts	"	each kind.

Any unusual work, such as viaducts, trusses, girders, arches or stone culverts. Common Exc. and Emb. should include all extra ditches, channels, highway crossings, etc.

All road crossings and points of water supply, names of all towns, and of property and other boundary lines as far as known.

All breaks in stationing to be indicated as follows: When the difference is less than one station the profile

will be made continuously and the discrepancy indicated by two heavy black lines, and the words "long" and "short station" with its length.

When the error is for more than one station, if there be a gap in the stationing, an equal space will be left on the profile. When there is a duplication of stations the profile will be broken and lapped over, so as to leave the stations at the bottom of the profile in all cases uniform and continuous. Every ten stations must be marked in tens, and every fifty stations marked in full.

At each end and on the back of the profile a title showing the character of the survey, whether preliminary or final; the corporate name of the Railroad Company for which the survey is made, the opening and closing station numbers, the proposed beginning and ending points of the survey and the name of the Locating Engineer, and Leveler. The Engineer must see that this title is marked in ink upon all profiles sent from his office or camp.

Tracings shall be made in suitable sections from the original profile and sent to the Chief Engineer, from which the necessary blue prints will be made for contractors.

RECORDS.

The note books used will be the transit book, level book, memorandum book and topography book. Memorandum books are the same size as transit and level books, but have blue rulings forming small squares The latter are to be used for keeping notes of water-ways and for entering general items of information in regard to the line.

Field books should indicate each day's work, giving date.

All subjects contained therein ought to be indexed and notes of adopted or abandoned lines marked as such. Notes must be made so plain that they may be understood by any one.

Notes of preliminary surveys must be kept with as great care as if for the final location. The work of each day should be compiled and recorded in the evening, that no delay may result from the loss or defacement of a field book.

All notes should be paged in pencil.

The original transit, level and other notes should be sent to the general office when the survey is completed. They must also be consolidated, as far as possible, in a new book; giving a revised and complete record of alignment, levels, topography, right of way notes, and other data pertaining to the line.

Note books must not be marked on the outside of the cover, but upon the first ruled page of the book, the title must be written in ink in the following form:

Corporate name of the Railroad.
Name and number of line.
Name and number of book.
Character of survey.
Stations and dates of beginning and ending the notes.
Names of note-taker and Engineer.

Original notes should be preserved as they are the only ones admissible in a court of law.

ESTIMATES.

Estimates should be kept up with location and recorded on the profiles. They ought to show the cost of the work by sections.

The prices to be put on the work are usually furnished by the Chief Engineer, together with copies of form No. ———, which should be closely followed.

Care should be taken to include everything necessary to complete the work ready for operation and use.

Estimates may be made from suitable diagrams or tables of center heights.

When the side slope becomes an important factor, the proper corrections should be made, see Trautwine's and Wellington's diagrams, etc.

The following table shows the effect of side slopes on quantities and indicates when corrections should be applied.

In the level column the prismoid is taken of such length that the volume is 100 yards. The other columns show the volume of a prismoid of the same length and center height on the various side slopes given.

Table of % increase due to slope of natural surface.
20-ft. roadbed slope 1 to 1.

Center Cut Feet	Level	5°	10°	15°	20°	25°	30°
5	100	102	106	114	127	150	190
10	100	101	104	110	120	137	160
15	100	101	104	109	118	133	154
20	100	101	104	109	117	131	151
25	100	101	103	108	117	130	149
30	100	101	103	108	116	130	148

Table of % increase due to transverse slope of the natural surface 16-ft. roadbed slope 1½ to 1.

Center Fill Feet	Level	5°	10°	15°	20°	25°	30°
5	100	102	111	129	158	235	507
10	100	102	108	122	148	206	441
15	100	102	108	121	146	203	422
20	100	102	108	120	145	200	414
25	100	102	108	120	144	199	410
30	100	102	108	120	144	198	407

On preliminary surveys topography should be used on grade lines and at critical places for the purpose of making a paper location, and from this the preliminary estimate is to be made.

Preliminary lines to be thus used must be laid close to the line the final location will follow.

PREPARATION FOR CONSTRUCTION.

Before the work of construction is commenced upon any route the Division Engineer carefully examines the line to see if any improvement can be made in the location, and he should submit to the Chief Engineer maps and profiles of any changes which he may think desirable; but no changes should be made without approval.

Each Division Engineer usually submits for approval, to the Chief Engineer, a list of all buildings, sidings, Y's, etc., with proposed location of same, required on all work.

The arrangement of all stations, terminals and sidings, the location of water tanks, and all matters having a bearing upon the operation of any line should also be submitted to the Chief Engineer for criticism before being constructed.

When approval is obtained, the Division Engineer at once makes formal requisition for said structures, always giving point of delivery.

RIGHT OF WAY.

As soon as the construction of a line has been approved, the Chief Engineer issues the necessary instructions for securing the right of way, which generally is uniformly 100 feet in width, except where additional land is required for station grounds, borrow pits, waste banks, or other purposes. A width of 200 feet should be secured at all important streams and at other points as below.

Widths of Right of Way Required Where Material Is Wasted or Borrowed.

Ht. of Embk.	Width of R. of W.
8 ft.	120 ft.
10 "	140 "
12 "	160 "
14 "	180 "
16 "	200 "
18 "	220 "
20 "	240 "
22 "	260 "
24 "	280 "
26 "	300 "

When land owners are willing to sell the earth off of additional ground wanted at a reasonable price, 100′ of right of way will be sufficient if a double track Ry., with

slopes for excavation or embankment can be placed thereon, but 200′ should be taken on all important streams.

The right of way should be secured as rapidly as possible, contracts for the same being taken and forwarded immediately to the Division Engineer's office, where the deeds will be made.

The description of irregular tracts which are acquired by the Company, will be by metes and bounds, obtained by actual survey, and properly referred to the center line of railroad and also to some permanent landmark.

The description of right of way through government subdivisions will be made in the following form:

"A strip, piece or parcel of land one hundred feet in width, situated in the North-West Quarter of the Northwest Quarter of Section Ten in Township Two North, Range One West (S. 10 T. 2 N. R. 1 W.)............ County,.............(State or Territory), and having for its boundaries two lines that are parallel with and equidistant from the center line of the railroad.

"For a more particular description reference may be had to the plat drawn upon and made a part of this deed."

The description of lots in platted tracts should be in the following form:

"Lot Seven (7), Block Six (6), in Smith's Addition to the town of.......County of......., State of....... according to the recorded plat thereof."

All plats drawn upon deeds should give ties to the government survey points or to some permanent points, so that the land can be located from the description of the plat.

RIGHT OF WAY MAPS.

After the line has been finally located and right of way secured, a right of way map should be secured and made in the Assistant Engineer's office.

Right of way maps should be made on a scale of 400 feet to the inch, corresponding to the scale of ordinary profile paper and should show the location of stations, the beginning and ending of each curve, the amount of curvature and the amount of the angle. They should show all section lines, quarter section lines and other land lines.

Measurements to section corners should be made as frequently as possible. The maps should show the width of right of way at all changes in such width, and the distance from the center line to each line of the right of way on the right or left.

In recording deed upon maps, the property described should be platted upon the right of way map from the actual description in the deed regardless of any plat that may be attached to the deed, unless the deed makes the map a part of the deed.

The progress of fencing done on the right of way should be indicated on the right of way map.

Right of way maps when completed should be forwarded to the Chief Engineer, accompanied by all deeds.

BRIDGE SOUNDINGS.

Before construction the sites of all the bridges should be sounded to determine the character of the foundations required.

Soundings may be done by a party of three men under a foreman and provided with the following equipment:

1 Team and heavy wagon.
1 Sounding rod in sections.
1 Drill ordinary (1 inch bar 8 feet long).
2 Pipe wrenches.
2 Steel clamps to raise rod.
1 Spoon.
2 Water pails.
1 Axe.

The sounding rod described below is designed so that it may be made wherever there are light pipe fitting appliances. The connections are reduced in diameter to obviate their extra resistance in sticky holes. The sounding rod is made of four ten feet sections of one inch gas pipe (1⅜ inches external diameter). Into both ends of each section a 6 inch piece of ¾ inch gas pipe is welded so that it projects ⅞ of an inch outside the 1 inch pipe. These projecting ends are then threaded on the outside and connection made between them with the ordinary ¾ inch couplings 1⅝ inches long with inside thread. These are kept in stock by plumbers, fitters, etc.

The drill bit is made of a one inch steel rod 12 inches long and pointed as an ordinary rock drill with edge 1¾ inches wide, the line across the widest part of the bit, for this work, being one inch from the extreme point. The upper end of this bit should be welded to a round rod of soft iron 1¼ inches in diameter, and one foot long, the connection at the weld being tapered. The free end of this iron rod is then drawn down and threaded to fit into the standard coupling. Soft iron is used in order to spare the dies in cutting the thread.

Several of these welded up-drill bits should be provided to avoid the delay of working with a dull tool.

This sounding rod is to be used as an ordinary churn drill, and the sections are connected or disconnected by using the pipe wrenches.

In addition to the sounding rod, a drill made of 1 inch round steel 3 feet long and with a point similar to that of the sounding rod, should be provided for starting holes.

The clamp is a piece of steel of the size and form of a monkey wrench. It is made to fit the pipe snugly, so that when a lever is put under the handle, the clamp will jam against the pipe and the latter may thus be withdrawn from the hole.

Two clamps with levers are used, one on either side of the pipe to neutralize the bending and sticking due to side strain.

The spoon is a 3/8 inch iron rod five or six feet long, to the lower end of which a bowl 1½ inches in diameter is welded at right angles. It is used for removing gravel and mud when beginning soundings.

Where rock is known to be near the surface, test pits will give better results than soundings.

In making test pits for bridges, the pits should be dug long and narrow, so that the digger with a long handled shovel may throw out the dirt backward over his shoulder from each end of the pit alternately. In this manner very deep pits may be dug by one man, single casting.

Where a pier is to be built, holes must be drilled from the bottom of the pit to ascertain the character and thickness of bed rock.

Notes of the position of the holes, where soundings are made or pits dug as well as depths and character of materials encountered, should be taken on the ground and platted in the office, on ravine sections.

RESIDENT ENGINEERS.

Assistant Engineers usually give personal attention to the instruction of Resident Engineers in regard to cross-section measurements and notes, and should from time to time take notice, that the work is properly done and notes carefully kept. They should see that each Resident Engineer has a correct profile of his residency, showing grade lines, curves, bridge and culvert notes, and notes of all special work, such as changes of water course channels, rip-rap of banks, location of road crossings, etc., etc., and that all such notes are scrupulously observed and the work done accordingly.

Resident Engineers will, as a rule, be allowed a rodman and tapeman, and when necessary a team with driver. The rodman must be capable of handling instruments and cross sectioning, the tape man capable of handling the rod. The teamster is to make one of the party in the field. (For equipment and supplies see appendix.)

Resident Engineers, upon arrival on their residencies, will immediately notify the Chief Engineer, and Assistant Engineer of their post office, express, telephone and telegraph address.

ALIGNMENT AND CHECK LEVELS.

The Resident Engineer will, as quickly as possible, check all curves and tangents and put in spirals. (See appendix; "Vertical Curves.")

The length of spiral and offset for each degree of curve is furnished by the Assistant Engineer with the approval of the Chief Engineer. For details of spirals, see the treatise and illustrations entitled: "The Six Chord

Spiral," following appendices at end of construction accounts and immediately preceding the section on "Maintenance of Way."

Run check levels over the residency and report at once any discrepancies found.

At junctions, Y's, etc., he will see that all curves, if not of the proper degree to fit the standard turnouts, are properly compounded for this.

He will place a bench mark close to each bridge for cut-offs for piles and foundation elevation.

Resident Engineers will not be allowed to make any change in grades or alignment; or location or size of bridges, culverts, etc., but must promptly call their superior's attention to any possible changes that they consider beneficial or economical.

Engineers must carefully reference the beginning and ending points of all curves and points of compound curves. Also such other points as may be important. This may be done by setting two hubs at an angle of 45 degrees and 135 degrees on each side of the tangent, say 100 feet from the P. C. or P. T., as the case may be. The hubs should be driven down level with the ground, and a stake marked with the proper notation to witness the point. By this arrangement the P. C. or P. T., may be found by the measurement or by the intersection of the lines.

The line may be referenced, near grade points, by measuring two equal distances, in a straight line, either on one side or both, at right angles to line and taking magnetic course of the reference line. The equal distances serve as a gauge of the length of tape used, and if one point be lost, the magnetic bearing will help in replacing the station.

FINAL LOCATION STATIONS.

The final location stationing is to be maintained throughout, and all records and work are to conform to it. In case of errors found in one station, maintain the stationing by recording the station long or short, as the case may be, giving its correct length. In the case of cumulative error, due to incorrectness of location chaining, prorate so as to bring the stations in agreement with those of the location.

CROSS SECTIONING.

All cross sections should be entered in the Cross Section Book as taken. Even if the cross sectioning cannot be carried continuously across a residency, the entries should be made continuous as though it were, leave two or more blank leaves at the end of each mile, to be used for the summary.

Each piece of cross sectioning should be carefully indexed in the Cross Section Book, station to station.

Vertical curves are required at all grade intersections. In "sags" the rate of change should not exceed one-tenth feet per station. On summits curves should be short to facilitate drainage.

On vertical curves the grade elevation of each full station should be entered on the profile and also in the level book.

Cross section should be taken and slope stakes set at every point where a difference of elevation between the center line of the two cross sections exceeds two feet, and always every 50 feet, treating half stations as though they were full ones. In staking out grading have number

of station marked on face of center stake and cut or fill marked on face and number of station on the back.

On slope stakes at full stations have cut or fill marked on the face and number of station on the back. Have + Stations marked with last figure of full station with a +. Thus, for station 729+63, mark "9+63."

Cross sections should be taken at all mile posts for convenience in calculations.

Take cross sections and set grades where the shallow side of the cut comes to grade, and where the shallow side of the fill does the same.

It is usually sufficient to note the plusses at which the deep sides of the cut and fill come to grade.

Where it is expected to strike rock or its equivalent, the preliminary cross section may be made at a slope of ½ to 1. This will in part allow for the compound sections as they develop on construction.

All embankments at bridge ends are to be staked out with the roadbed two feet wider than called for in the specifications, tapering back to the specification width in 50 feet.

As these ends of bank are most exposed to rain wash it is usually better, if the water-way will permit, to make them wedge shaped instead of with the usual rounding at the base, thus giving footing material to support the corners.

Banks over 20 feet high, where considerable shrinkage is anticipated, may also be staked out for a roadbed two feet wider than usual.

Any isolated mass of rock which occurs between slope stakes, but is not included in the regular notes, should be separately noted and added to the sum total of the material in the cut.

STANDARD PLANS.

Resident Engineers will call for blue prints of the standard plans of all structures that will be erected on their residency, and, in accordance with them, make all necessary detailed drawings, showing thereon all dimensions in conformity with the standard plans furnished.

A copy of these detailed plans for masonry, etc., must be furnished to the Contractor's foreman. In concrete work the forms should be designed by the Resident Engineer, giving sufficient dimensions to enable the contractor to properly erect the forms.

Blue prints of ravine sections showing the design of each opening, together with the bill of material for each, will be supplied to the Resident Engineers, who will promptly upon receipt, check up all bills and at once notify the Assistant Engineer's office of any discrepancies or errors.

No changes will be made by the Resident Engineer in the standard plans of any structure or in the length of pile and frame bridges shown on the ravine sections, but he will call the Assistant Engineer's attention to any such change as he may deem advisable, and upon approval of any change will forward to the Assistant Engineer a revised bill of material for the whole structure.

He should see that the necessary drain boxes, culverts, etc., are promptly ordered and placed so that contractors will not be kept waiting to complete the fills.

FIELD PROFILE AND BOOKS.

The Resident Engineer will obtain the necessary data to enable making up at once, on plate "A" profile paper, a field profile similar in every respect to the final profile,

showing particularly in pencil the approximate quantities and contemplated overhaul.

He will keep a transit book, field cross-section book, bridge book, pile recorder's book, and diary.

A title should be written on the fly leaf of the book, giving the residency number, Resident's name, and post office address, with a brief statement of what the book is used for. This title ought to be placed on the fly-leaf. Each leaf must be numbered or paged, dating each day's entries, and carefully indexing, in the front of the book, each separate piece of work. Indexing and paging should be done as the work is performed.

A field entry of notes on paper or in memorandum books, intended to be transferred to the proper book by the Resident Engineer or his subordinate should never be permitted.

This method of indexing, paging, etc., is to be followed with all books used by the Resident Engineer, including the final estimate book.

In the transit book should be kept all alignment notes, reference points, land and other surveys, together with all level notes, which may be taken in connection with any survey, so that complete notes of every kind of and small piece of work, may be entirely in one book.

The station for each mile will be given the Resident Engineer, and the beginning and ending of miles thus shown are to be maintained throughout in handling the work, and in all records.

STATION GROUNDS.

Resident Engineers will ascertain the location of all station grounds, and sidings as early as possible. All references to length of siding will be from H. B. to H.

B. unless otherwise stated. No borrow pits or waste will be allowed within the limits of the station ground without permission from the Assistant Engineer. Resident Engineers will obtain full instructions before permitting the contractors to commence work on station grounds.

CONSTRUCTION.

The Assistant Engineer in charge of construction should give as much personal attention as possible to the details of the work of construction, so as to be fully posted upon all points, such as classification of material, etc.

He ought to see that all work is done in accordance with specifications or instructions, and must be diligent to save expenses in all ways consistent with sound engineering.

He must make written reports to accompany force reports to the Chief Engineer of the progress of the work, calling attention to any want of proper energy on the part of contractors, or any disposition to slight or neglect their work.

The Resident Engineer will keep a diary, entering briefly all instructions given to contractors, date that each contractor began and completed his work, the date of beginning and completion of all openings and important pieces of work; also as a guide to classification notes regarding classified material, the manner in which contractors handle various kinds of material and any other matter that may be an aid or guide in making the final classification and estimate. This will be turned in with the final records.

The Resident Engineer must use the greatest care to see that his note books, profiles, etc., are not lost.

He should keep up his records as far as possible to obviate the serious consequences of such loss.

During the progress of the work of construction upon any division, the Resident Engineer must go frequently along the line, to see that all work is being faithfully and honestly performed in accordance with the specifications, and that cross section stakes are properly guarded and preserved.

Careful attention must be paid to the notes on the profile requiring special work, such as dykes, ditches, road crossings, etc., so as to arrange for the most economical performance of such work.

CLEARING AND GRUBBING.

Clearing must not be piled off the right of way, unless the contractor first secures the consent of the owner in writing, which consent is to be forwarded by the Resident Engineer to the Assistant Engineer.

Clearing must not be piled within the reach of high water, so that it might be floated back into the openings. Bear in mind that in all overflow districts there is a current both ways.

The specification clause as to burning all brush must be fully enforced.

In clearing allowance should be made for telegraph lines, which are usually 45 feet from the center line. Dead and leaning trees outside the right of way, which if blown down towards the telegraph line or track would obstruct or damage either, should be carefully selected and cut down and proper damages paid the owner for same.

Clearing and grubbing should be so conducted that

the top of no stump will be less than two feet below sub grade.

In general, borrow pits should be grubbed for their full width, and the grubbing paid for.

Large grub holes should be refilled and tamped.

Grubs should be burned or removed from the right of way.

ROAD-BED EXCAVATIONS.

Resident Engineers will give centers through the excavations as the work progresses to insure the contractors excavating true to the required slope.

Plowing should not be done nearer than one foot to the slope and all slopes must be cleaned down as the work progresses, and when material will permit, by pick, mattock or shovel.

Slope boards should be used in this work. They are usually furnished by the Company for use of the Contractor, to be returned to the Resident Engineer as soon as the work is finished.

If, as any excavation progresses, the character of the material changes so as to require a different base or slope, the Resident Engineer must re-cross section the work without delay and take such measurements as will enable him to calculate accurately the amount of material taken out.

On a scale of ten feet to an inch, all excavation cross sections involving classification should be platted. On these excavation areas, note the classification lines as they develop during the progress of the work.

When a cut contains material in excess of the amount required to make embankments, such excess ought to be hauled and used to widen the banks equally on both sides

of the center line within the limits of free haul, and if in the judgment of the Engineer, advisable, beyond it, paying for the overhaul.

It should be thoroughly understood that all excavated material is, if so desired by the Resident Engineer, to be hauled to the limit, where the cost of overhaul per yard equals the price per cubic yard of earth excavation.

In cases where banks are so low as to make haul impracticable, material will be wasted.

In such cases care must be taken to deposit it in such a way that it will not be washed back into the cut.

Wasting material is objectionable and will only be resorted to when it cannot be avoided.

Waste banks must be left in regular and sightly shape. If waste be above grade they shall not be nearer than 20 feet to slope stakes.

Waste banks are not allowed at mouth of cuts.

Line the back of waste banks so that a three foot fence berm is left, and see that waste banks are generally leveled on top so that they are not unsightly.

Whenever embankments are in excess, cuts within the limit of free haul (and at the discretion of the Assistant Engineer for a reasonable distance beyond it) should be staked out wider than the usual roadbed.

All change channel and cut widening work should be staked out early and liberally so that the contractors will have no excuse for filling everything in sight from borrow pits.

At passing tracks on the switch stand side both cuts and fills should be made three feet wider than usual for distances from the stand of 25 feet toward the station and 175 feet away from it, to enable the brakeman to overtake the train after throwing the switch.

In rock cutting, grades may be marked by white lead on the sides of rock cuts at a height of two feet above sub-grades.

The contractor must be obliged to take his cuts out to slope and down to grade, yet do so without waste of labor in unnecessary work.

While the work of finishing is being done, the Engineer must see that all rock cuts, and cuts that have boulders in the bottom, are taken out one foot below sub-grade, and that the cut is full width, so as to allow for a full ditch.

After the cut is out it must be filled in to grade with the best material at hand, leaving a ditch on each side of the cut for drainage.

If the contractor so desires he may take out half the width of a cut at a time and have it inspected. This to allow for handling the material back with the least labor.

In filling in rock cuts, broken stone from the side or bottom of cut not more than two inches in diameter, should be used, if possible, and the contractor allowed for the refilling.

Contractors will deposit on the side of the railroad, or at such places as the Engineer may designate, within the limits of haul, and convenient for handling by train or otherwise, any rock, or stone they may have excavated which may be suitable for rip-rap, slope wall, etc.

In piling, make piles at 90° with the track, leaving a four foot space between piles so that a number of men may be employed at one time at each pile to quickly load construction train standing on main line.

The use of powder in large blasts, such as seam, pot-hole, shaft or drift shots, may be restricted by the Engineer.

The position of charges must be watched by the Engineer to protect slopes of earth in a compound section. Thus, for a cut of six feet of earth overlying four feet of solid rock, the centers should be fired first and mucked out and then the cut widened by light side shots to avoid shattering slope.

SURFACE DITCHES.

Surface ditches should be staked out on the high side of cut and excavated at the same time cuts are opened.

Ditches should be neat and regular, placing all material excavated on the lower side in a continuous uniform bank with two foot berm, thus forming in a levee, and adding to the value of the ditch.

No surface ditch ought to be less than one and one-half feet deep, and two feet wide on the bottom, nor nearer than ten feet to the edge of any cut.

Ditches must be led away at the ends of cuts in order to prevent water running against embankments.

Where cuts are wasted, the waste bank should be made continuous on the high side of the cut to hold the surface water back.

In finishing excavate a surface ditch half-way between the waste bank and the high side slope, to keep all drainage from the waste bank out of the cut.

BERM DITCHES.

Where embankments are made from excavation, and there is no borrow pit to keep the surface water away from the embankment, berm ditches will be excavated, and made as large as the case may require.

All berm ditches will be staked out, and generally have the material excavated from them placed in the embankment before any material is hauled from the cut.

EMBANKMENTS.

When the clause in the specifications requires embankments to be built to the slope from their base up so that the whole may settle into a compact mass it must be enforced by the Resident Engineer.

Additions made subsequently are liable to slide off.

The bank must be made full and regular, and care must be taken to avoid sags between stations.

Particular care should be taken to guard against concave slopes.

The best material ought to be placed in the center of the bank under the roadbed and poorest in the slopes. All fills should be topped at least one foot deep with the best material obtainable.

Material unusually liable to shrink, such as frost clods, sods, etc., should be placed no farther in from the slope than it is below grade.

Sod and surface material from cuts should not be hauled into the light part of the adjacent fill, but further along and used in the slope where the bank is higher.

In building high embankments with wheel scrapers, the runways, where carried up into the bank should be made the full width of the embankment.

Runways allowed to stay narrow and hard packed cause uneven settlement of the bank after completion.

When necessary to work in freezing weather the earth

to be used in fills must be kept constantly plowed to reduce freezing to a minimum.

When embankments are constructed over culverts, or when they are to abutt against masonry, or trestle bridges, the earth forming such embankments ought to be tamped or otherwise made as compact as possible.

The contractor should be required to use the greatest care in such cases, that the masonry be not jarred, broken, pushed out of place or injured in any way, particularly when the mortar is green.

In turning streams, place the change at the outside of the right of way, flaring the opening of the change for the first hundred feet of its length in order to avoid erosive eddies.

Care should be taken to make embankments across old channels strong enough to resist the action of the current.

In such cases the width of the embankment should usually be not less than ten (10) feet from the center line on the side against which the current will act, with two to one slope.

SHRINKAGE.

Resident Engineers will consult with the Assistant Engineer as to the amount of shrinkage, if any, that may be required on the various embankments. This is governed by the kind of material, method of filling, proximity of bridges and nearness of the tracklaying.

This shrinkage, when required, will be placed on embankments before setting the final finishing stakes, and it must be placed uniformly on top of slopes. The contractor must be informed of the amount of shrinkage that he will be required to put on before he completes roughing in the embankment.

The average shrinkage is 10% on casting and shovel work.

7% on wagon work.
5% on scraper work.

A safe plan for shrinkage is to widen high banks from slope stakes up and shrinkage can be made up in ballast whenever necessary.

RIP-RAP.

When embankments are rip-rapped to protect them from action of water, that part of the embankment upon which the rip-rap is placed should generally be made with slope of two to one.

If the embankment has been finished at a steeper slope, the rip-rap should be so placed that its exterior slope shall be two to one and well backed. This is to avoid undermining.

When, however, the base of the rip-rap is on rock or its equivalent, the rip-rap may follow the usual 1½ to 1 slope.

Wherever possible the base of the slope should be ditched to give the rip-rap a secure foundation.

Stones should measure generally one cubic foot and the size of rip-rap should increase with the velocity of the stream.

The largest stones ought to be placed at the bottom and where the current has the greatest force, and must be laid by hand as closely together as possible so as to avoid large openings.

The ends of all rip-rap protection should be turned into the bank so as to prevent its being undermined or washed out.

Care should be taken to make a smooth connection between rip-rap and the paving of culverts and masonry.

SLOPE WALL.

Slope walls should be made not less than 1½ feet thick and their foundation well set down.

When it is intended to hold slopes at a deeper angle than 1½ to 1, they should be built with as much care as dry rubble work, and whenever possible backed with loose rock.

The bed should be at right angles to the plane of the slope.

BORROW PITS.

Borrowing from the sides should not be allowed on station grounds or sidings, except by special permission of the Engineer.

Material ought to be hauled from the excavations made at the ends of such sidings or station grounds.

If borrow pits are necessary they should be made on the extreme outside of the right of way and with care for drainage.

No borrow pits should be made where they might cause injury to the roadbed.

No borrow pits ought to be excavated below the grade of openings through which they are to drain, due allowance being made for setting down culverts, etc., and the contractors should be shown how to excavate the pits, so that when finished they will drain their entire length.

If necessary the Resident Engineer should run levels along the pit to effect this.

Borrow pits for light fills should be rather narrow and deep to diminish the percentage of sod in the bank.

Commence borrow pits three feet further out from the slope stakes than berm calls for, as slips tear off the corner.

Slopes of borrow pits should be 1½ to 1, both sides.

Incline the bottom of the borrow pit away from embankment so that drainage will be toward the outside of the pit.

On the outside of the borrow pit leave three feet for fence berm immediately inside of right of way limit and line the borrow pit generally so that it will not be unsightly.

Do not cut borrow pits directly through to creek channels, but leave 15 feet of creek berm.

In finishing, dig small ditch for drainage in a suitable place as far away from embankment as possible.

At bridges, where possible, widen original channel from within four feet of toe stakes, on 2 to 1 slope, down to stream bed, dishing the center one foot.

This is to be done generally for full width of right of way.

The quantities to be borrowed may be arrived at from the plotted haul and the contractors should be instructed where, and how much to borrow, so that the necessary borrow may not be exceeded, leaving excavation to be wasted.

Berms of the following widths must be left between the slope stakes and the edge of the borrow pit:

For banks under 3 feet in height, berms 6′ wide.

For banks from 3 to 10 feet in height, berms 8′ wide.

For banks over 10′ in height, berms 10′ wide.

CROSSINGS.

In locating crossings consult the right of way deeds and comply with any stipulation contained therein.

Grades on crossings should not exceed six per cent.

The usual width of a farm crossing should be 12 feet, and that of an ordinary highway crossing 20 feet with the usual slopes, and with 20′ of level grade each side of center line. Top of road crossing should be one foot above grade.

Engineers should endeavor to secure, wherever practicable, at reasonable expense, undergrade or overhead crossings.

Bridges and culverts can frequently be utilized at slight expense for undergrade crossings for stock by making necessary openings in the right of way fence.

Street crossings in cities or towns will consist of a plank outside of each rail and the space between the rails fully planked, except for the flange groove, between each rail and the nearest plank.

Country road crossings and private farm crossings will consist of four planks, one on each side of each rail, and the space between the two inner planks must be well filled with broken stone or earth.

All the planks in a crossing must be cut to an even length and laid evenly.

Planks must be secured to a tie by a sufficient number of 8 inch boat spikes; common track spikes must not be used.

The inside plank next to the rail should be laid so as to leave two inches between the head of the rail and the edge of the plank. On the outside of the track the under

edge of the plank should be notched to set over the spikes and the plank close to the rail.

The ends of the plank ought to be rounded and beveled. Crossings should be put in promptly to avoid any inconvenience to the public.

FINISHING.

The contractor must have the requisite plant for finishing up, before giving finishing stakes.

This is to avoid having cuts and banks completed to the neglect of ditches, borrow pits, drainage, etc.

One and one-half to one slopes on fills should be combed down to true prismoid if necessary, for the contractors are paid for so making them.

No concave slopes are permitted, either in cuts or fills, or unsightly bumps in the cut slopes.

FINISHING STAKES.

All grading should be finished according to the standard roadbed sections.

In finishing embankments on tangent, put in the grade on hubs placed in center, leaving the foreman to set his own side stakes.

On curves one grade stake should be placed at the center and one on each high side at the edge of the bank.

In cuts a grade stake on each side, both on tangents and curves, should be driven in the foot of the slope at the half width of the roadbed.

Stakes should be set at each full and half station.

The tops of all grade stakes should be chalked for identification.

Before acceptance, the grade over the embankments and through cuts ought to be checked, to see that ditches are of proper depth and fully excavated, and that the

roadbed between grade stakes is without sag and true to the grade line.

Neat, true to the prism grading work ought to be required. Before acceptance see that the prisms are full. This may be done with a short slope board with a small level attached.

Where the line is to be ballasted, in order to facilitate drainage, the roadbed at sub-grade should be crowned on tangents by raising the center four inches above the sides, making due allowance for ballast in establishing final grade elevation.

SUPER-ELEVATION OF CURVES.

On all curves the roadbed ought to be finished to conform to a super-elevation equal to two per cent of the width of the roadbed for each degree in the index of the curve. The outer edge of the roadbed should be raised above the grade at the center line half the super-elevation and the inner edge of the roadbed depressed below the grade of the center line half of the super-elevation, the center line remaining in conformity with the profile grade plus shrinkage. Thus, for a 16 ft. roadbed on a 4 deg. curve the super-elevation would equal 1.28 feet or .64 feet above the grade of the center for outer edge and .64 feet below the grade of the center for the inner edge.

Curves having bridges within their lengths should be treated in the same manner as at other points.

The distance out in both cases should be set at a point corresponding with the width of the roadbed desired, which in general will be 16 feet on embankments and 8 feet each side of the center line. On sharp curves proper corrections should be made in the slope stakes due to the

curve elevation. It is desired that embankments shall be full and strong on the outside of all curves.

This inclination of the surface should be carried in full amount through the whole length of the curve and should gradually be brought to the level at distances beyond the ends of the curve equal to 25 feet for each degree in the index of the curve, unless the tangents be too short.

Super-elevation will not be graded on any roadbed greater than for an 8 degree curve.

Material used for ballasting, widening banks, or raising sags should be procured at points where the removal of same will benefit the roadbed by widening cuts, reducing grades, ditching, etc.

Engineers should give this subject special attention.

MASONRY.

Special attention ought to be paid to all masonry, to see that it is done strictly in accordance with the plans and specifications, great care being used in laying out the work.

All culverts and masonry structures should be staked out and a plan furnished the contractor's foreman, on which the location of all stakes must be shown.

The stakes for the inside and end building lines should be set far enough back from the work to permit of its being carried on without disturbing the stakes, and so that a line stretched from tack to tack will intersect at the nearest corners.

In putting in abutments, piers, etc., the footing course must be spread below the wash, and the reach of frost, unless the foundation is on rock or its equivalent.

In general where piling cannot be driven, a safe supporting power of two tons per square foot may be taken.

Excavations for stone masonry will in general be staked out one foot greater than the outside dimensions of the footing course.

In concrete foundations without grillage, they may correspond with the dimensions of the footing course.

Sufficient slope should be given to reasonably obviate caving during the laying of foundations.

It is usually best to cross section the larger foundation areas in squares, so that, in case of enlargement by caving, extra sloping, etc., a complete record of the surface is at hand. Stakes should not be put in on these squares, the slope stakes being set independently.

When so directed by the Engineer, all material excavated from foundation pits, within haul of embankment, is to be placed therein and estimated as excavation, and borrow quantities reduced accordingly.

A complete record with sketches and dimensions ought to be kept of all masonry built, particularly showing the foundation work, which may not afterwards be accessible.

The depth of the foundation below some fixed point in the structure as top of coping, must in every case be given.

Resident Engineers should allow no important structures, such as abutments, piers and large culverts, to be started until their immediate superior has examined and approved the foundation.

In the case of minor structures, box drains, etc., the Resident Engineer's approval will be sufficient.

He must examine the foundation for all sub-sills, trestle bents, culverts, etc., to see that they are satisfactory.

Engineers should guard against taking any risks by

building on foundations subject to settlement, wash, frost, etc. Even when solid rock is reached several feet should be drilled into to prove it is not a shell.

The Resident Engineer should ask for special instructions in cases where there is no certain foundation.

CULVERTS.

Every culvert should be built so that it can discharge water under a moderate head without damage to itself.

Culverts should be laid out at right angles to the center line whenever practicable; the channel being changed if necessary.

They should as a rule be set low enough to drain borrow pits.

All culverts must be made to drain themselves as well as their tributary areas.

The greatest care should be used in preparing foundations to keep them below frost and from becoming undermined. For masonry or dry wall culverts all soft material must be removed and the walls carried well down in trenches to a secure foundation.

The space between the walls must be carefully paved. Paving is usually 12 inches deep and consists of flat stones set upon their edges, the longest dimensions being at right angles to the water-way.

They should be of sufficient depth to reach through the whole paving and so laid that the spaces between them are a minimum.

Culverts ought to be laid to as great a grade as their safety and the nature of the ground will permit, at the same time insuring a proper inlet and outlet.

Culverts should be protected at both ends by a curb of large stone, extending three feet below the floor.

The lower end must receive special attention, to keep the back wash from undermining, and to give free and safe vent to the water for some distance from the slope.

The foregoing also applies to wooden box culverts.

Vitrified pipes, when used for culverts, should be at least three feet below sub-grade, and crowned a few inches at the center to allow for settlement.

When putting in pipe culverts, the bottom of the trench ought to be rounded, cutting depressions for the sockets.

If the natural foundation be poor, it should be removed and good material substituted. Stone in contact with the pipe should be avoided.

Care should be taken that the spigot end of each section of pipe enters the socket of the next section to its full depth and is blocked up, so that the lower interior surface of each section is flush with the connecting one.

The mortar for cementing the joints should be composed of equal parts of sand and cement thoroughly mixed just before using.

The earth should then be tamped thoroughly under the pipe, taking care that the hardest tamping is not done directly under the center of the pipe (which should be slightly relieved) but on each side of it about 30° from the vertical.

When filling in, use drag scraper to build up walls of well trodden earth, parallel to and as close as possible to each side of the pipe, giving the space over the pipe a more moderate tamping, thus imitating the conditions of a pipe laid in a trench.

When double pipes are put in, they should be placed far enough apart to permit of thorough work between them.

The upper end of a culvert may sometimes be effi-

ciently protected by a wooden bulkhead, whose foundation is deep enough to prevent undermining or upheaval from frost.

This may be made by planting inclined posts against the slope and on each side of the culvert mouth (but not too close) so that their lower ends are well down below the natural surface. Planks are then spiked on clear down and fitted snugly around the pipe. Before the wood decays the bank, aided by rip-rap, may be sufficiently consolidated to take care of the culvert.

BLIND DRAINS.

Blind drains are made of rough stones thrown in without particular order, except that the largest stones should be at the bottom.

The top of the drain should be covered with brush or sods.

The use of blind drains is objectionable, and should be restricted to cases where the amount of water to be disposed of is known to be very small.

PILING.

Stake out all pile bridges in advance of the driver, and in accordance with the standard plan, setting a stake for each pile.

In general it is best to use the near face of the bent as its station number; for then centers can be plumbed up from hubs below, etc.

In this case the piles must be driven immediately back of the stakes set for them.

Pile Inspectors are appointed by the Assistant Engineer, and they report to the Resident Engineer of the residency upon which they are recording.

It is their duty to watch the driving of piles at all times, and to keep a record of all piles driven.

The Resident Engineer ought to require piles to be driven to such depths as will make them secure against being washed out by the scour of streams as well as against sinking under the load.

Formula for safe load in pounds:

$$\frac{2WH}{S+1}$$

W=wt. hammer in lbs.
H=Fall in feet.
S=Set of pile in inches under last blow.

As the simplest rule, some specifications require that the pile be driven until it will not sink more than five inches in five blows, hammer one ton, fall 25 feet.

The Resident Engineer provides the Pile Inspector with a standard level book to be headed as below, and with ravine sections showing the pile openings on the residency, together with bills of piling ordered for each opening, which the recorder will enter in the pile record book.

Resident Engineers are held responsible for the proper keeping of the pile record by the recorder.

The bents of each bridge are numbered consecutively with the stationing, the bank bent being numbered 1, and the piles in each bent lettered, A, B, C, D, etc., from left to right, when looking with the stationing.

Sketches of all pile foundations, other than tresties, must be given, in order that the piles in the record may be properly identified.

The pile record shows on the left hand page:

1st. Station.
2nd. Bent No. and pile letter.
3rd. Kind of pile and whether treated or untreated.
4th. Length put in leads.
5th. Penetration below surface.
6th. Length under cut-off, to be filled in subsequently.
7th. Penetration under last five blows.
8th. Weight of hammer and last drop in feet.

On the right hand page all remarks bearing on the work should be made.

The Pile Inspector should see that long piles are not used where shorter ones will amply suffice.

To prevent splitting or brooming the piles in driving, the top must be well chamfered all round or pile rings used.

For hard driving the piles must be shod.

When necessary to drive to a great depth, and piles of adequate length cannot be obtained, one ought to be spliced upon the top of another.

The first pile having been driven as far as practicable, it must be cut off squarely to receive the other or following pile, which must also be squared and set upon top of the other one already driven. The piles are then to be squared on four sides and fastened together by spiking on pieces of scantling.

Pile Inspectors when leaving a residency should leave the pile record book with the Resident Engineer. This record book of the Inspector is turned over to the Bridge Engineer, who makes up a complete record for each

bridge by separate bents, either pile or frame, with complete bill of material. Where the piles are driven by the Railway Company, the foreman in charge is expected to keep the above records and report them to the Resident Engineer.

In giving cut-offs on pile bents, or curves, drive a tack in the pile under the inside rail (the grade pile) at some convenient whole number of feet near the cut-off and below it, if possible, blazing the pile where the tack is driven and marking the feet, up or down, to cut-off on the blaze.

This distance should be recorded in the notes.

The outside pile is treated in the same way, allowing for the elevation according to its distance out.

On tangents tacks should be driven in the two outside piles, the intermediate cut-offs being lined in by the sawyers.

If possible try to avoid driving the tacks above or at the exact height of cut-off, as in case of error the record is lost.

In every case the distance from the top of the pile to the cut-off should be noted, as this with the pile record fixes the length of pile below cut-off.

TIMBER STRUCTURES.

All timber should be sawn or hewn square, of proper dimensions, free from large wanes, shakes, rot, large and unsound knots, or any defects likely to impair its strength and durability.

The use for which timber is intended must be taken into consideration, all imperfect sticks being excluded from places where considerable loads are to be sustained,

particularly where the piece is under transverse strain or tension.

Frame trestles should have foundations composed of piles or mud sills.

When, in the judgment of the Engineer, the ground is so hard that piles cannot properly be driven, mud sills may be used.

In preparing for foundations, for trestles or other structures, care should be taken to have the bed entirely in excavation. To facilitate this step bents should be used in extreme cases.

These sills ought to be settled as nearly as possible to a permanent bearing by the use of heavy rammers.

Care should be taken not to bury with earth any portion of the sills or posts.

Foundation pits for trestle bents should be arranged so as to give good drainage.

Great care must be taken in framing trestles and all timber structures to secure a perfect fit at all joints. Shimming should never be permitted.

All adjustments on height of structures, due to settlement or other causes, must be rectified by jacking up from the bottom to the proper elevation.

Unless the road is to be ballasted the bridge stringers should be set 3 inches above sub-grade.

Allowances for ballasting should be made on all masonry, piers, abutments, etc.

In general:

1st. The foundation must be firm and unyielding.

2nd. The pile bents must be jacked and braced to right line.

3rd. The cut-offs must be true and piles water tabled.

4th. All timbers must be sized to a true and full bearing on piles and other timbers.

5th. Ends of caps and ties must be sawed to line from end to end of bridge; ties sized to full bearing without shoulders, guard rails well secured in line.

6th. Sway and other bracing must be adequate and well bolted and spiked.

7th. Bank walls, dump boards and supports must be in good shape, the track approach true and firmly bedded, earth or ballast kept away from the ends of stringers or wall plates.

8th. All framing must be so arranged that water is not retained.

9th. Water-ways must be cleaned out and reinforced with rip-rap if needful.

10th. The whole structure must be in good line and surface completely bolted and washered throughout.

11th. All creosoted structures shall be doped with creosote wherever cut framed or bored.

ABUTMENT AND PIER CRIB FILLING.

Abutment and pier cribs should be filled with angular stones of a size and character satisfactory to the Engineer, which should be placed in the cribs without damage to any portion of the structure, and as the inspectors direct.

FENCING.

Fencing should be placed on the exterior boundaries of the right of way as shown on the profile or right of way map.

It should be built to conform with the standard plans of the Company, and the local fencing laws, which should be consulted for this purpose.

Posts should have, at 500 foot intervals, a wire brace twisted tight from the top to the bottoms of the two adjoining posts.

Suitable corner braces should always be put in.

All wires should be stretched until they hum when lightly tapped.

QUANTITIES.

Resident Engineers should calculate quantities as the work proceeds.

The calculation should be completed before the completion of the grading of the roadbed and carefully recorded.

Graduation quantities will as a rule be calculated by the method of average end areas. For this Resident Engineers must generally take cross sections with no greater difference than 3 feet between the center heights of adjoining cross sections.

Returns should be made to the nearest full yard, omitting tenths.

In calculating quantities at the ends of cuts, where the solid has only one end area, estimate as a pyramid instead of as a wedge; i. e., the end area by one-third of the length.

As a check, see that the sum of the pay quantities less the waste equals the total embankment.

In all calculations reserve the better man for the final checking. A contrary course sometimes results in no check.

The following tabulation will show the limit beyond which the cross sections must either be taken closer together or else the prismoidal corrections used.

TABLE OF PRISMOIDAL CORRECTIONS.

Diff. in Cent. hts.	Correction in cu. yds. per 100 ft. Stations for slopes of ¼:1	½:1	1:1	1½:1
1	0.2	0.3	0.6	0.9
2	0.6	1.2	2.4	3.7
3	1.4	2.8	5.6	8.3
4	2.5	5.0	9.9	14.8
5	3.9	7.7	15.4	23.1
6	5.6	11.1	22.2	33.3
7	7.6	15.2	30.3	45.4
8	9.9	19.8	39.6	59.3
9	12.5	25.0	50.0	75.0
10	15.4	30.9	61.7	92.6
11	18.7	37.4	74.7	112.0
12	22.2	44.4	88.9	133.3
13	26.1	52.2	104.3	156.4
14	30.3	60.5	121.0	181.4
15	34.7	69.5	138.9	208.3

Note:—That the corrections vary directly with the slope ratio and with the square of difference of center heights. For prismoids less than 100 ft., multiply above corrections by the length in feet and point off two decimals.

In unusual cases, particularly on mountain work, the prismoidal corrections may, by special instruction from the Chief Engineer, be used throughout.

These corrections are to be added together for each cut or section and deducted in gross from the end area volume.

Note the convenient rule for the area of three level sections—One-half center height+sum of distance out+ ¼ road-bed+sum of side heights.

Irregular and compound sections should be platted on cross section paper on a scale of 10 feet per inch, the classification marked on them distinctly and the end areas calculated by the usual methods.

The prismoidal formula should be used for masonry.

REPORTS.

Resident Engineers should forward each week a concise report, compiled from their diaries, showing the progress of the work, good and bad methods of handling the same, and other items of importance; also any recommendations for increase of force or change in the method of dealing with the work.

This ought to be accompanied by a force report giving by sections, stations and contractors, the full average force which the contractor has on the ground during the time covered by the report, and which might if conditions were favorable, be used on the work to advantage.

For this purpose, men and animals are not to be counted unless the contractor has at hand the necessary plant for them.

In the remark column the number of days actually worked by this full force should be given. If half force works full time enter a half number of days, etc.

Then, on the back of the report, note the causes of time lost, such as "Idle 3d and 10th on account of wet cut, station 548" or "Borrow pits allowed to freeze, section 17," etc.

Resident Engineers should report at once by letter, telephone or telegraph, any matters which require the prompt decision of an higher authority.

PROGRESS PROFILES.

Progress profiles should be sent each month to the Chief Engineer's office properly marked to show all work done up to and included in the last estimate, on the part of the road in charge of the Engineer.

They should show all work done both graphically and by percentages the total for each section and all material delivered to date.

Not only grading but also bridges and culverts, with their exact location, description and the location of all buildings, or structures of any kind, wells dug, main track, sidings or "Y's" laid, etc., should be shown.

The depth that piles are driven below the surface of the ground should be indicated by dotted lines, showing the point of lowest pile in bent; the mud sills of trestles should be shown by a short heavy line, and on steep side hills the elevation of each mud sill should be marked in the same way.

When track is laid, the end of the track should be marked for each day.

The completed profile is generally returned to the office of the Assistant Engineer at the close of the work.

The marking on progress profile by months should be diagonal or section ruling at an angle of 45° to right,

same to left, same both right and left crossing and uniform shading with lead pencil. The section shading should open with about twenty lines to the inch. The pencil shading must be moderately heavy to blue print well. No attempt need be made to reserve a special form of shading for any one month. Thus, January and October, if not adjacent, may have the same shading.

The months may be marked on the shading with their customary abbreviations or with Roman Numerals.

Jan.	I.	July	VII.
Feb.	II.	Aug.	VIII.
Mar.	III.	Sept.	IX.
Apr.	IV.	Oct.	X.
May	V.	Nov.	XI.
June	VI.	Dec.	XII.

Open spaces in the shading should be left for these marks, which should be used often enough for quick identification. (Several on each section.)

REPORTS.

Maps, profiles, estimates and general records should be completed while construction is in progress, and the data for making them close at hand.

The standard record book for graduation is furnished each Engineer in charge of a residency.

The notes should be written in ink when final, but not until then. The record should contain cross-section notes, and all other data pertaining to the calculation of quantities, classification in detail, ground and grade elevations, alignment, material or labor account, *and the data*

for every item embraced in the final estimate, including force accounts.

Following the notes of each section, there should appear the notes of all rip-rap, road crossings, drainage and all other grading work which has been done upon that section.

Excavations for foundations should generally be entered in the bridge book as their cost is chargeable to bridges, trestles and culverts.

Following these notes, there should be a general summation of quantities of the different classes of work, concluding with a statement of the "final estimate" for the section.

At the end of each mile give also the names of all the grading and clearing contractors engaged on that mile; noting the beginning and ending stations of their work, together with the date they began and completed their work.

All solid rock cross-sections ought to be inked in a separate plat cross section book, showing fully the classification lines, and at the end of each cut its total classification.

A final summary will be made, giving the estimate by totals in each section.

The record must be kept up, as far as possible, while the work is in progress, and should be carefully indexed and turned in to the Assistant Engineer at the close of the work, and finally checked in his office, before a final estimate is given.

In the standard record book for bridges (called the Bridge-Book) the final notes pertaining to truss bridges. trestles, cattle guards, culverts, pipe drains and other structures required for drainage should be entered in ink.

This must show quantities, classification, disposition, dates and the notes necessary to check the quantities, together with the name of the sub-contractor actually doing the work.

On the left hand page should be entered all bills of timber, piling and other material; also the amount actually in structure and disposition of the surplus. On the right hand page a sketch of the structure, showing in the case of pile bridges, a ravine section, the kind of material penetrated with penetration of piles, similar in outline to standard ravine section.

In the case of truss bridges record the floor system separately from the truss proper.

Care should be taken in this record throughout to distinguish between treated and untreated material, either piling or sawed lumber. Show whether creosote or chloride of zinc is used in treated material.

For masonry structures, and all culverts of whatever kind sufficient dimensions must be shown to enable the quantities to be checked.

In all cases care must be taken to show the nature and kind of material the structure is founded upon; giving the quantities, classification and disposition of the material excavated from foundation pits.

Under the structure ought to be entered the date work was commenced and the structure completed, the name of the sub-contractor actually performing the work, and that of the inspector.

LIST OF ABBREVIATIONS.

For Class of Structures.

W. B. Wooden or timber box culvert.

S. B. Stone box culvert.	P. C. Pile culvert.
S. A. Stone arch culvert.	P. B. Pile bridge.
T. P. Tile culvert pipe.	T. B. Trestle bridge.
C. P. Cast culvert pipe.	H. T. Howe truss.
B. D. Blind drain.	C. T. Combination truss.
P. G. Plate girder.	I. T. Iron truss.

D. S. Draw span.

The Resident Engineer should see that each Record Book has its title written in ink upon the first ruled page of the book in the following form:

BRIDGE OR GRADUATION RECORD BOOK.

Of sections......to............of the.................. railroad.

From Station..........to Station..........

..............................Asst. Engineer.

...........................Resident Engineer.

The Bridge Book should be carefully indexed and turned in with the final estimate.

PERMANENT BENCH MARKS.

As soon as the construction permits, the Resident Engineer should place permanent Bench Marks at least every half mile; and when possible establish them on masonry bridge seats, stone culvert steps or other substantial and permanent objects. When such structures

are not on the work with sufficient frequency, requisition should be made for standard Bench Marks.

All these should be recorded in the last pages of the Record Books and on the final profile, giving both location and elevation.

FINAL PROFILE.

Upon the completion of work upon any Residency, the Resident Engineer ought, as soon as practicable, complete and send to the Assistant Engineer a correct profile of the division, showing all information required on profiles, in accordance with the actual construction.

This profile should be made as per standard sample (see preceding instructions *Profiles*) on a continuous roll of plate "A" profile paper, in scale 200 feet wide, long enough to leave 18 inches of blank paper at each end.

To the usual title should be added:

Final Profile, Residency No. 6.
Miles, 18 to 27.
Station, 1081 to 1556.

Give the station and plus of both ends of pile and girder bridges, centers of end pin of pin bridges, center of pipes and all covered culverts, center of road crossings and cattle guards; names of rivers, creeks, town and stations; length of sidings; H. B. to H. B., alignments, Bench Marks and final quantities by sections and structures from the record books.

STATION PLATS.

Station plats should be made on a scale of one inc equals 100 feet.

They should show the name of the station, the coun and province in which they are located, and the title the branch and system to which they belong.

This title should be in the lower left hand corner possible.

The quarter section, town and range should be plai shown upon the map, the number and kind of conveyan of each piece of property, as also the North point; da scale and number to be shown as specified for right way maps.

Make the drawing on tracing cloth, using the ungla side.

The degree and curvature of the turn-out and alignment of all the tracks should be shown compl together with the distance out from the center line main track, when said tracks are parallel to the m track.

The location station of the head block should be sh and the character of the turn-out or switch designa such as stub-switch, split switch, or whatever the na of the device may be.

Take plusses to all land lines and show them pl outside of right of way line, so as to place them ou the way of future tracks and buildings, which will c figures.

Land divisions, such as sections, townships and ran should be written with the top of the letters to the N regardless of the other lettering on the map.

School District numbers should be reported and

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District numbers should be reported and w

ten in on the map in pencil with date of obtaining same, as they are liable to change without notice.

Make center line a fine, clear line rather than a heavy one, on account of making scale measurements from it. It is unnecessary to rule in double lines.

HAUL AND OVERHAUL.

The positions of the mile posts are fixed, and the contractor must arrange with his sub-contractors accordingly.

When material is hauled past a mile post, that fact and the quantity moved must be stated in the column of remarks in the estimate books, on both miles affected. For example: "On mile 50, five hundred cubic yards hauled into embankment from mile 51." All excavated material (from cuts or borrow pits) must be estimated and placed in pay column on the mile upon which such material was excavated.

All calculations should be checked in the office of the Assistant Engineer before a final estimate is given.

This work is facilitated by the use of tables, diagrams or a twenty-inch slide rule.

The foregoing method pays for a full yard of overhaul the moment that yard passes the boundary of any full overhaul station.

No fractional overhaul stations are considered.

According to the usual definition of overhaul (*i. e.*, center of bulk of cut to center of bulk of fill after the free haul has been made) the contractor is always overpaid by this method.

On level ground the percentages of overpayment when the 100 feet haul station is taken as the indivisible unit are as follows:

		Per Cent.
First one hundred feet of overhaul	...	100.
" two " " " "	...	50.
" three " " " "	...	33.3
" four " " " "	...	25.
" five " " " "	...	20.
" six " " " "	...	16.7
" seven " " " "	...	14.3
" eight " " " "	...	12.5
" nine " " " "	...	11.1
" ten " " " "	...	10.0

These excess percentages would average a great deal less on ordinary work since the cuts and fills usually increase with the length of haul.

On level work the excess would be eliminated, if the free haul by the 100 foot unit method be made 50 feet longer than by the center of bulk method.

The hundred foot unit method favors any length of haul to some extent, but the premium is much greater on the short hauls, and it is a good one to use when it is specially desired to help them.

If closer figures be desired, the horizontal length of haul lines on the diagram may be ruled so that they differ by 50 feet in length instead of 100 as shown.

In this case, the excess percentages on level work would be cut in two, for then every 50 feet would be taken as the indivisible unit of haul. Similarly taking every 25 feet as the unit the 100 feet excess percentages would be divided by four, the price paid per unit being always proportional to its length.

In other words, the smaller the unit the nearer the approach to an exact measure of overhaul.

Under the same contract a 100 foot unit should not

be allowed to one subcontractor, while another is held to a 50 foot unit. Some uniform method clearly understood in advance by all parties to the contract should be used.

It is often the best plan to adopt a rule for measuring, that slightly overpays in a definite manner.

This tends to avoid disputes, and, in case estimates have to be submitted to the courts, overhaul figures particularly when approximate graphic methods are used, will not add to complications.

Note that in the diagram the true measure of the haul over 500 feet is the part shaded, the limiting inside lines being drawn perpendicular to the ends C and A of the 500 foot haul line.

Thus the sum of the right and left shaded areas between the 500 and 600 feet lines is approximately,

$\frac{1}{2} \times (600-500) \times 97$ yds. $=$ 48.5 yds. overhaul, similarly between 600 and 700.

$1\frac{1}{2} \times (700-600) \times 101$ yds. $= \underline{151.5}$ " "

Total 500 to 700 $= 200.0$ " "

The estimate from the diagram by 100 ft. units is 97 yds. $\times$ 1 sta. $+$ 101 yds. $\times$ 2 stas. $=$ 299 yds.

An excess of 49.5%, which is about the same as the overpayment for the first two hundred feet of level work.

EXCAVATION.

Sta.	Yds. Per Sta.	Total.
0	130	630
+50	90	500
1	120	410
+50	100	290
2	90	190
+50	60	100
3	40	40
+73	0.0	

OVERHAUL EARTH.

97	Cu. Yds.	1	Station	97
101	"	2	"	202
	Total overhaul to 700			299

OVERHAUL ROCK.

80	yds.	1	Station	80
82	"	2	"	164
	Total overhaul to 700			244

EMBANKMENT.

Sta.	Yds. Per Sta..	Total each.	Total Solid Rock.
3+73	0.0		
4	50	50	31
+50	30	80	50
5	50	130	81
+50	70	200	125
+80	60	260	163
6	10	320	200
+50	80	400	250
7	115	510	318
+50	580	590	368
8	120	710	444

In the foregoing the amount of solid rock is taken which will in each case when broken to swell 60% of its volume in place fill the yardage marked in the earth column opposite.

In making this diagram the total yardage, both in cuts and fills both ways from the grade point, is summed up

to the various cross section stations within the limit of haul. These stations are platted on a horizontal line to the scale chosen.

Then the total yardages from the grade point to each station are platted vertically under that station to the yardage scale chosen and connecting lines drawn as shown.

Then a horizontal scale is slid downwards until it measures between the cut and fill projections 500, 600, 700 feet. These horizontal lines are then ruled in.

This haul diagram may be platted on plate "A" profile paper to the following scales:

Horizontal 1 in.=200 to 400 feet.
Vertical 1 in.=200 to 2000 yds.

Shrinkage and expansion affect distances hauled but not yardage hauled; this latter is always to be measured and estimated in excavation.

In the diagram 1 yard solid rock is taken equal to 1.6 yards in embankment. Hence dotted line is platted in proportion, vertically. Thus at the point where the regular cross section quantities sum up to 160 yards, the dotted line passes through the 100 yard point.

Free haul points and all other quantities determined from diagram of this form are to be entered into the notes as final, no further numerical calculations being necessary.

The haul diagrams from which final estimate has been made are to be turned in with the final cross section notes and become part thereof.

The Engineer will note expansion of rock by taking stations between which, cut and fill actually balance on the ground.

Haul should be estimated separately for each cut, and paid for on the section from which the excavation is made.

That phase of railway construction coming within the scope of the railway civil engineer has thus far been chiefly described by Mr. Stephens.

Regarding the actual laying of ties and rails and the ballasting, lining and surfacing of the tracks, these matters will be found pretty well covered in section two of this volume. Those who may require a more comprehensive and detailed account of the subjects will find it in a very excellent work entitled "Notes on Track" by Mr. W. M. Camp, from which are given a few brief extracts pertinent to the work of laying the ties and rails, as follows:

"The work of track-laying may be analyzed into two distinct operations, namely: That of forwarding materials and laying them down at the front; and the work of joining these materials together and building the track structure. The methods pursued in the former operation have to do principally with the speed and cost of track-laying, and in the latter with the excellence of the track, for, on general principles, good track can be laid just as cheaply as poor track, if intelligent labor be employed and placed under competent supervision. In the organization of a track-laying crew there is usually a superintendent of construction, assisted by a clerk and three foremen. There is a foreman over tie distribution, a foreman with the rail car, and a foreman over the strappers and spikers. The clerk keeps the time of the men and looks after ordering and accounting for the camp supplies. Circumstances sometimes demand both a clerk and a time-keeper. If the work is done by contractors

the railway company has its own superintendent or engineer, who is usually assisted by a clerk and an inspector or two, to see that material is not wasted and that the work is done properly and according to contract specifications. The number of inspectors required always depends a good deal upon the honesty and reliability of the contractor. There is also a receiver of material employed by the Railway Company, through whose hands all the track material must pass and be accounted for by the time it reaches the front.

"The Superintendent of Construction usually gets about on horseback, and for convenience of communicating with headquarters it is a good plan to build the telegraph line as fast as the track-laying progresses. When this is done the superintendent of track-laying usually has a clerk who is a telegraph operator, and the line is temporarily connected with the office-car and put in working order as often as the car is side-tracked, or every evening at the end of track if the outfit train is kept moving with the work. Usually there is a night watchman to take care of the locomotive, and sometimes another to look after the train and outfit. On extensive work, however, particularly when some distance from the base of supplies, there is usually a night train crew to make up the material train or the following day's work and bring it to the front. The baking for a large crew, and sometimes part of the cooking, is done during the night by an extra force in the kitchen car."

PLACING TIES.

This is covered fully in section 2 of this volume under the general head of Cross-ties and sub-heading of Spacing Ties. The practice on different roads is given, also

tables giving number of ties per mile. Writing on this subject, and continuing, Mr. Camp states:

"It will usually be found cheaper to distribute the ties with teams, if there is good opportunity to work them, than by any other method. Ten teams in one day can haul out the ties for a mile of track. The wagons should be coupled up short and provided with a sort of rack, so that a full load may be put on in a single pile. A V-shaped affair built on the order of a hay-rack is sometimes used. It saves much labor of handling to unload the ties from the cars to the wagons direct. A plank chute, with rollers, attached to the door-posts, with the outer end slung from the top of the car, is sometimes used for passing the ties from the car to the wagons."

* * * * *

"The ties are thrown down and then lined and spaced. If the faces of a tie vary in width the wider face should be placed downward, thus taking advantage of a larger bearing surface for the ballast. In lining the ties two men are given a stout cord or small rope about 1,000 feet long, called the tie line, which they stretch out and wrap around stakes set opposite every center stake at a distance of half the standard tie length. On curves the tie line should be staked about every 25 feet. On some roads it is the rule to line the ends of the ties on the south or east side of the track; on other roads they are lined on the side of the track on which the mile posts are located, and on many roads the inside of curves is always taken from the line side; but any question as to which is the proper side to line is of comparatively little consequence. On double track it conduces much to the appear-

ance of things to always line the ties on the outside of both tracks. As the ties are laid down they are dropped approximately to the tie line, and the two men referred to, one working at each side of the track with a light pick, one end of which has been cut off near the eye (commonly known as a 'picaroon'), pull the ties to the line and space them at the same time. It saves time to have a man with a sort of T-square gage turned down at the end so as to reach over and catch the end of the tie, measure from the long corner and mark across the face of each tie, on the line side, with a large plumbago pencil, a gage line for the edge of the rail base. This can be done rapidly, and it saves the spikers the trouble of gaging each tie to a notch on the hammer handle, as it is usually done. Among track-layers this man is known as the 'fiddler.' In some cases his tool consists of a piece of 6″ board with a cleat across one end, to catch over the end of the tie, and a car door handle screwed on top, with which to carry it."

* * * * *

"Men a little accustomed to the work will rapidly place the ties about the right distance apart, by the eye, without hardly taking thought. Ties should be placed squarely across the track, and never obliquely to suit joints which do not come exactly opposite. On curves it is usual to put the butt or wide end of the tie to the outside of the curve. It is the practice to some extent, however, to vary this arrangement to suit the class of traffic. Thus where the curve is to be elevated fully for fast passenger traffic the larger end of the tie would be placed under the inner rail, so as to give more supporting surface to resist the additional weight of freight trains thrown to that side of the track by reason of the slower speed. But

if the freight traffic is the more important and the curves are elevated for a compromise speed, the larger ends are placed under the outer rail, so as to better resist the additional weight thrown upon that rail by passenger trains running at higher speed."

* * * * *

"In order to space the ties with reference to the joints, in advance of the laying of the rails, a light pole as long as the standard rail is trailed along over the ties and the proper locations for the joint ties are measured off. In laying the Columbia and Western branch of the Canadian Pacific Ry., a piece of band iron 30 ft. long, with a ring on the front end, to pull it along, and copper rivets at intervals corresponding to the tie spaces, was used for this purpose. The use of a spacing pole or line requires the attention of two men and gives a good deal of bother. Where the rails are laid broken jointed requiring the arrangement of two sets of joint ties in each rail length, it is better to let the tie spacing go, except roughtly, until after the rails are laid down—and it is perhaps the better plan in any case. Two men working with the picks and two men with bars to lift the rails, can then space the joint ties and divide up the other spaces to conform thereto. Owing to variation in rough measurements the joint ties should not, in any event, be located far ahead of the rails. To avoid discrepancies and the necessity for rearranging the ties at intervals the pole measurements should be checked occasionally by referring back to the rails."

Joints, Supported and Suspended.—This subject is treated at length in Section 2, under the sub-heading of "Rail Joints," but in regard to what are generally known as "three-tie joints," Mr. Camp, continuing, says:

"Since long splice bars have come into use the term 'three-tie' joint has gained currency. Such, however, is only another name for a supported joint, the 'three-tie' idea arising from the fact that the splice extends over three ties. Strictly speaking, the two outer ties of such a group are not joint ties, because they lie neither under the joint nor adjacent to it. For the sake of accuracy the terms joint and splice should not be used interchangeably; nevertheless their use in this manner is pretty general."

* * * * *

THE RAIL CAR.—"From the point where the materials are unloaded from the construction train the rails, and in some cases the ties, are hauled ahead on strongly built cars known as 'rail cars,' also commonly called 'iron cars' and 'steel cars.' The car is usually about 8 ft. long, with 4x8 inch side sills and four cross pieces, and it should carry a load of 15 to 18 tons, or, say, forty or forty-five 80-lb. rails. On both ends of the car, near each corner, there should be a roller, for use in unloading the rails. Planks are sometimes nailed to the under side of the frame, between the two middle cross pieces, to form the bottom of a box for carrying tools and small supplies. The wheels are usually about 16 inches in diameter and the treads of the same should be 7 or 8 inches wide, so that the car may be safely run over loosely-lying rails, before the track is spiked. If the wheel treads are narrow in a case of this kind it requires a great deal of care to keep them from dropping between the rails on curves. A rail car off the track, with a load of rails aboard, is often the cause of serious delay to the whole work. The axles should be as large as 2¾ or 3 inches in diameter, and the wheels should be spoked, so that

they can be spragged in emergency. For hitching the team to the car there should be a large ring eye-bolt at each side sill at the middle. For hauling rails it is usual to have a team of two horses hitched in tandem, the driver riding the hind horse and driving the one ahead. In this way, they pull close beside the track, on a rope 25 to 30 feet long, and are driven at a trot when returning with the empty car. A man with a brake stick should always ride the car and be ready to unhook the rope in case the car should get the start of the team."

Placing Rails.—"As the limit to the length of track that can be laid in a day, after the ties have been placed, is fixed only by the rapidity with which the rails can be laid down, much depends upon the skill acquired by the rail-car gang in handling rails. The succession of movements in laying the rails to place is about as follows: There is a man with a wheel chock to stop the car at the right place at every move ahead. There is a squad of five men (more or less, according to the weight of the rail) near the head end of the rail who seize it in their hands and carry it ahead as soon as the car stops; after a little practice they pull the rail off so as to drop it almost to place. Two men, known as 'heeler' and 'hip heeler,' at the rear end of the rail, move it in line with the rail behind; the heeler inserts an expansion shim; the men at the head end give the rail a pull backwards, to close up on the shim; one man who watches the rails for lip carries a bar, to hold the end of any rail in line, in case of necessity, and the car is pushed ahead. A clamp gage is sometimes used on the rails ahead of the car to keep them from spreading, especially on curves. Where quick work is desired there are two parties handling rails, unloading from both sides

of the car at the same time. The opportunity to do this is not so favorable if the rails are laid broken jointed, which is the reason that contractors prefer to lay them square jointed. On track with but few curves greater speed can be made in laying rails square jointed than when laying them broken jointed, because there is not so much starting and stopping of the car.

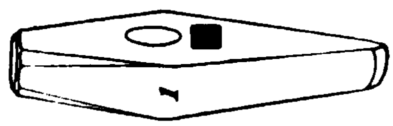
"One rail-car can handle the rails for laying a mile of track per day. In fast work two rail-cars are used. One of the cars is loaded while the other is being unloaded, and in order to get the loaded car past the empty one, when pulling the loaded car to the front, the empty car is turned up on its side, on the ties, outside the rail, and held there or tilted back and propped in a leaning position while the loaded car is passing. A portable turntable has sometimes been used for this purpose. The men with the rail-laying car come back with the empty car each time as far as the point where it is passed by the loaded car coming out, but if the work is properly managed they should pass near the front, thus delaying the rail-laying crew as little as possible. The crew at the rear should be large enough to unload the material, curve the rails, if necessary, load the ties and the rail-cars and keep things moving at the front. In some cases where the ties are hauled ahead by teams the rail-cars are loaded by the rail-laying crew. Where such is the practice it pays to load up two cars with rails, before starting out, and take them both to the front. After the first car has been unloaded it is taken off the track and the second car is run forward and unloaded. This arrangement saves the time that would otherwise be lost in taking the crew back to load and return with the second car, and it gives the material

train a chance to run back and do switching. On every carload of rails hauled ahead enough splices, bolts and spikes are taken to lay the rails. The splices are thrown off at every joint passed and spikes and bolts, in the original kegs or boxes, at such intervals as they are needed. In some instances the heelers attend to dropping off the fastenings.

"In laying track around the curves the inner rail gains upon the outer rail at the rate of about 1.03 inches per 100 feet per degree of curvature. Provision should therefore be made to lay enough short rails on the inner side of the curve to compensate for this gain. In practice such rails are seldom shortened more than 1 ft., but a shortening of about 6 inches is considered preferable, as then the relative position of the joints on the two sides of the track need not change so much. It is most convenient to crop the rails with a view to save one or two bolt holes, which will usually shorten the rail about 6 inches. If 29½ feet is the length of the short rail used each one so laid should be placed when the inner rail has gained 3 inches instead of waiting until it has gained all of the 6 inches, as then the joints on opposite sides need not get more than 3 inches out of the desired relative position. If the tangent beyond the curve is laid square-jointed, the last short rail laid in the curve (or the only one in a short curve) should be cut to such length that it will bring the joints even at the end of the curve, whether it comes the standard length for the short rail or not. The short rails for use on curves are usually loaded with the rest and are designated by some mark, such as a band of white paint around the rail or by painting the end of the rail white or both.

"It is not considered standard practice to lay in main

track a piece of rail shorter than 14 feet. Gaps shorter than this are closed by taking out a rail of full length and using two cut rails as 'closers' for the whole distance. As an example, suppose that a gap of ten feet is to be closed. Taking out a whole rail leaves a gap of 40 feet, which is closed by laying two 20 feet pieces or two pieces of other convenient lengths, neither being shorter than 14 feet. On the outer side of curves it is not desirable to use short lengths at all, especially pieces shorter than 20 feet. On short curves it is an easy matter to avoid the use of a short piece by slipping the rails back to carry the gap ahead to the tangent. Short lengths of rails laid on either side of a curve should be curved before laying, whether the rails of full length laid on the curve are so prepared or not. To secure a proper fit for the splice bars the ends of any rails which may have become burred by sawing or other cause, should be filed smooth on the fishing surfaces. For this purpose sharp cold chisels and large bastard-cut files are useful. The same treatment should be applied to splice bars burred at the ends."



COLD CHISEL.

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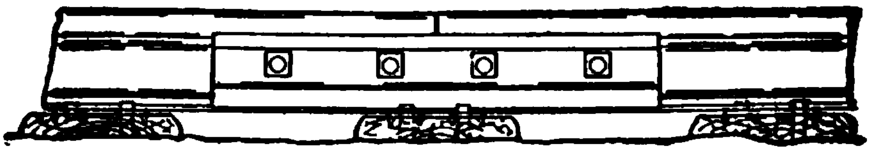
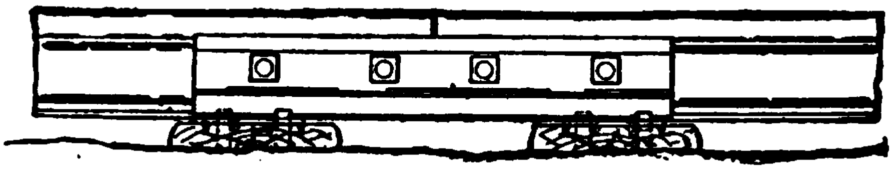
"In passing from even to broken joints in entering a curve, or vice versa, upon leaving the curve, the work need not be delayed to await the cutting of a rail, for the changed arrangement of the joints may be started and the connection made temporarily by turning out the end of a whole rail and laying a switch point. A rail may then be cut at convenience, to fill the gap, and the spare piece from the rail so cut should be taken ahead to the other end of the curve, or else to the next curve,

If the curves are only a short distance apart (say less than 1,000 feet) it is usual, where the practice of changing the relation of the joints at curves is followed to continue the broken joints throughout the intervening tangents." (See "Rail Joints" in Section 2 for Even and Broken Joints.)

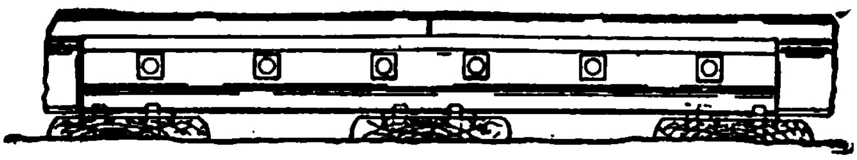
SPLICE BARS.



1. One Tie Supported.



2. Two Ties Suspended.



3. Three Ties Supported.

"Touching the question of square or broken joints for double track, arguments are presented both ways. Some prefer square joints in order to keep the joint ties square when the rails creep. If the rails creep on broken-jointed track the ties are slewed out of square and the rails are pulled out of gage and alignment. This difficulty may be overcome, however, by putting anchor splices or anti-creepers on the solid rail opposite the joint. Others prefer broken joints for the reason that, with traffic in one direction, one rail will generally creep more than the other, and if the joints are laid even to start with, it is only a little while until the joint ties become slewed out of square, making it necessary to drive one of the

rails back, to bring the joints opposite and straighten the ties around."

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HANDLING CURVED RAILS—"It is well to so arrange the work that the rails may be taken from the curving blocks or machine and loaded directly onto the cars; otherwise the expense of handling is considerably increased. After rails are curved they should be handled with special care and should not be thrown.

"In laying where curves are numerous the rails should be curved in the material yard or before they are shipped to the front. A man from the engineering department is usually given charge and supplied with a note book giving the location and lengths of the tangents and curves of the line. This man has charge of loading the rails and the ties (in case the ties are of different kinds, so that a harder quality may be had for the curves) and he is supposed to so arrange the shipments that cars loaded with material for the curves are forwarded in their proper order. By a little calculation the cars can be arranged to come exactly in the order needed. To avoid confusion, cars loaded with rails for certain curves should be labeled by marking, on a shingle or card tacked to the side of the car, the station numbers of P. C.'s between which the material is to be used. In building the Columbia & Western branch of the Canadian Pacific Ry., each car was marked with the initial station for any curved rails carried, and the first and last rails of each curve had the station number painted on them. Rails curved for different degrees of curvature should not be mixed, or carelessly loaded on the same car. To avoid inconvenience the curved rails for different curves

should be placed in separate piles, divided, if necessary, by pieces of board. It is also customary in loading curved rails not to place rails for more than one curve on the same car, the balance of the carload, if there is room to spare, being finished out with straight rails."

"Following behind the rail-laying car come the splicers or 'strappers,' as they are commonly called. These men are usually divided into two parties—the 'head strappers,' who should be quick and steady with the fingers, to put on the splices and one bolt in each splice to hold it in place, and the 'back strappers,' who put in the remaining bolts and finish tightening the splice."

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"The first thing to be done is to get the ends of the two rails in line, at the same level, and take out the expansion shim. This the head strapper does by prying on the rail with his wrench in one hand, and grabbing up with the other hand a chip, pebble or some other object to put under one of the rails to hold it up even with the other; it then takes but an instant to put the ends in line. Then, standing inside the rail, if the bolt heads come on that side, he puts the splice bars in place, not by feeling for a bolt hole in the rail with his finger, but by sighting down with the eye—a more rapid method. He then puts a bolt through one of the middle holes, gives the nut a few turns with the fingers or wrench, far enough to hold the splice in place, and goes ahead to another joint. The head strapper should work some little distance in rear of the rail laying, as, if he gets too near, the removal of the expansion shims may permit the rails to be bunted back and close the joint openings.

"The back strapper next comes along, puts in the full number of bolts and tightens them."

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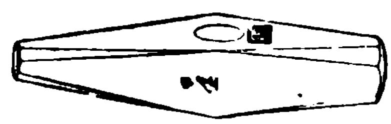
"He should carry a spike maul, and after the bolts are fairly well tightened sledge the splice bars together by striking each a hard blow between every two bolt holes and at the ends; and each bolt head should be lightly tapped. This hammering will pulverize the oxide scale between the surface of the rail and the splice bars and drive the splice bars to a closer fit. The bolts will be found loose after this hammering and should then be tightened again about as tight as a man can conveniently pull on them with an 18-in. wrench, using both hands and standing on his feet. Such an adjustment will not be too tight, as it would if the splices were worn to a closer fit with the rail, as is the case after trains have run for awhile. Nuts should be put on flat side to the washer or nut lock, and before they are tightened the splice bars should be adjusted to bring the bolts squarely across the rail. A good fit for the bolt head cannot be obtained unless the bolt is at right angles to the splice. After the track is ballasted and lined the bolts should be thoroughly gone over again, for after surface kinks have been taken out and the rails put in line some of the splices will be found to have loosened. Some roads require that within a month after traffic begins running the bolts shall be tightened again."



SPIKE MAUL.

"Where rails of different heights come together in main track the splice bars should be stepped and made to fit accurately and it is sometimes found necessary to offset them to suit a difference of thickness in the two webs or a jog in the alignment of the same. The joint in this case should be made 'supported' and an iron shim should be put under the rail of lesser height, or a

stepped shim under both, to bring the top surfaces of the rail-heads even. This shim should be spiked to the tie, like a tie-plate, so that it will remain in place. A splice made to fit the two rails of dissimilar section is generally known as a 'compromise' or 'offset' splice."

SPIKING.—"Spiking is one of the most important details of tracklaying, because it is very troublesome to remedy when wrongly done. Spikers should not be pushed, for if they are they will surely slight the work in some respect. Two men drive spikes together, delivering blows on opposite sides of the rail at alternate intervals. Right-handed men should be paired with right-handed men, and left-handed with left-handed. Frequently right and left-handed men are paired together, principally because it looks better, perhaps, to see both facing the front; but there is nothing gained in rapidity thereby and the work cannot be done so satisfactorily. While driving a spike the spiker invariably pulls or starts the tie toward himself at each blow. It is clear, therefore, that two men driving from the same side of the tie will both move it, unless it can be held up more tightly than can always be easily done, and both will tend to move it in the same direction; but when they stand facing each other the tendency to pull or start the tie one way is balanced by a like tendency from the opposite direction, and the tie is not moved in being spiked."

SPIKE.

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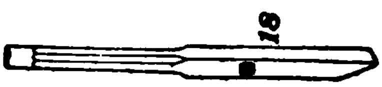
"The line side of the track is of course spiked first. To begin with, the spiker on the outside sees that the tie end is at proper distance from the rail, driving it through when too long, or having his partner drive it from his end when too short; he then sets his spike. When a gage mark is not placed on the tie face he measures by a notch out on his hammer handle. This length should be such that a tie of standard length projects equally beyond both rails when they are spiked to proper gage. When the rail is too far out of gage with most of the tie ends the man holding up the ties, called 'the nipper,' should take his bar and throw the rail over to the approximate gage. After the spike on the outside of the rail has been set, so as not to allow the tie to shove through while it is being raised to the rail, the nipper holds it firmly up against the rail base while the spikers do the rest. Before the spikes are driven, however, the men should see that the tie is properly spaced from the others and square across the track. If this is not attended to the spikes will be out of true when the tie is shifted to proper position.

"The nipper is usually provided with a pinch bar (a crow bar is a poor tool for this purpose) and a block of wood about 24x12 ins. in size, for a fulcrum, with a spike driven into it for a handle, and ordinarily they answer the purpose well enough."



PINCH BAR.

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"Spikes should not be leaned to suit the swing of the spiker's hammer, but should be driven perpendicular to the tie face. It requires some vigilance to get men to abide by this rule, since one must bend his back a little

in order to do so, but it must be insisted upon. Where a spike has been driven slantwise it is a difficult matter to catch the head with a claw-bar when the spike must be pulled, and if the spike is inclined under the rail the latter will ride the neck of the spike and cut it. One aid to good spiking is to have the hammer handles the full regulation length of 3 ft. Ordinarily men will not drive spikes properly unless they are watched and criticised occasionally; let foremen not forget this. The spike should be started plumb, with the side of the point against the rail flange, so that it will crowd the rail all its way down. The finishing blow should tap the head down to a firm hold upon the rail flange, but not too forcibly, lest the spike be broken off or cracked under the head or the neck of the spike be forced away from the rail flange. The effect of this last blow is to spring the rail base slightly into the fibres of the wood and start the spike further into the tie, so that the spikes are made to hold the rail-base to the tie with a force of several hundred pounds. This drawing force is caused by the action of the wood fibres, which are forced inward with the spike and act somewhat like a pawl to resist any tendency to pull the spike back.

"The usual practice is to drive two spikes in each tie for each rail, and to drive them staggered; that is, on opposite sides of the same rail the two spikes stand near opposite edges of the tie face. In ties sawed or hewn on four faces spikes should not be driven nearer than 2½ ins. to the edge of the tie face and in pole ties they should be driven at about ¼ the width of face from the edge of the face. Spikes should be so driven that they have no tendency to swing the tie askew to the rails before the track is ballasted. This requirement can be

fulfilled by driving both outside spikes the same edge of the tie face and both inside spikes near the other edge of the face. For the same reason spikes should not be driven in the middle of the tie face; besides, with pole ties, the heart of the timber being under the middle of the face, the spike does not hold so firmly when driven there and it is also more liable to split the tie or to come where the tie most usually checks open."

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"On the gage side of the track, every third tie at the farthest, that is, at least one-third of the ties, should be spiked to the gage; but where the ties lie very unevenly and on curves of short radius, the rails should be spiked to the gage on alternate ties. It is more important that men spiking with the gage should be experienced and skillful in driving spikes than it is with spikers on the line side. The nipper for the gage spikers should keep the rail thrown nearly to the gage ahead of them. If the line side is left badly out of line after being spiked it is well to throw it into fair line before spiking the gage side. Where the tie that is being spiked is held up firmly the rail can be moved slightly to gage by a stroke sidewise with the hammer; if not, or if it be moved slightly out of gage after the spikes have been started, but before they are down, it can be drawn powerfully by slightly bending over the spike on the side from which the rail is to be removed, and as the spike is driven further down it will crowd the rail over."

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"In order that the spike may crowd or 'draw' with most force when driven in this manner it should be started

perpendicularly to the tie face, the same as when driving a spike under ordinary conditions and not slantwise under the rail, as some wrongly suppose; then it should not be bent over until after half way down, since the body of the spike is then firmly held in the tie and, by bending the spike and driving straight down upon it, a powerful side pressure is exerted against the rail. In curves of short radius a sharply pointed pick is the best tool for crowding and holding the rail to gage. If the gage is tight the inside spiker starts his spike first, and if it is loose the outside spiker starts his spike first, and the first spike started should put the rail to gage before the other spike is started. Then if there be no tendency in the rail to spring itself out of gage, both spikes should be put down together; otherwise the advantage should be given the spike first started. But if a slight bending inward of this spike will not bring the proper gage the rail should be moved by sticking a pick into the face of the tie ahead and prying it over. The gage should rest squarely across the rail just far enough in advance of the tie which is being spiked to be out of the way of the hammer of the inside spiker, and it should be kept there until the tie is spiked. The men who do the gaging cannot spike as rapidly as the other spikers, and where the ties are so soft that a spike can be put down with not more than three hammer blows, one spiker is enough to go with the gage; for where under such circumstances there are two, one will be standing still doing nothing a large part of the time; and so, to economize time, he might better form part of another spiking crew.

"Rails should be gaged to within almost a hair's breadth, because it can just as well be done that way after men become a little expert."

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"The gage should just come to place on being raised three or four inches at one end and let drop; if there can be any movement of it across the track it is too loose; if it will not drop to place it is too tight. The gages should all be tested and closely inspected by the foreman every morning, without fail. There is more necessity for watching gages in track laying than in track repair work, for irresponsible men will sometimes permit the rail to spring inward on the gage with such force that one of its lugs is loosened, and say nothing about it. It is the duty of the men spiking the gage side to see that all ties spiked are put square with the rails, and also to spike no tie having a warped or twisted face until it has been adzed to fit evenly with the rail base on that side. Of course it is taken for granted that when spiking the line side both edges of each tie face have been brought up evenly to the rail base on that side. Sometimes the necessity for adzing does not appear until after one end of the tie has been spiked."

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TRACK-LAYING MACHINES.—Regarding laying track by machines Mr. Camp says: "A track-laying machine is an arrangement of devices for running ties and rails to the head end of a material train. The Holman machine consists of a series of tramways or rollers about 20 inches wide arranged in frames or sections about 30 feet long, which are supported upon brackets attached to the stake pockets at the sides of ordinary flat-cars on which the materials for laying the track has been forwarded, no change in the cars being required. The brackets are in adjustable lengths, so that each tramway may be inclined slightly from the rear forward. The

HOLMAN-BURKE TRACK-LAYING MACHINE.

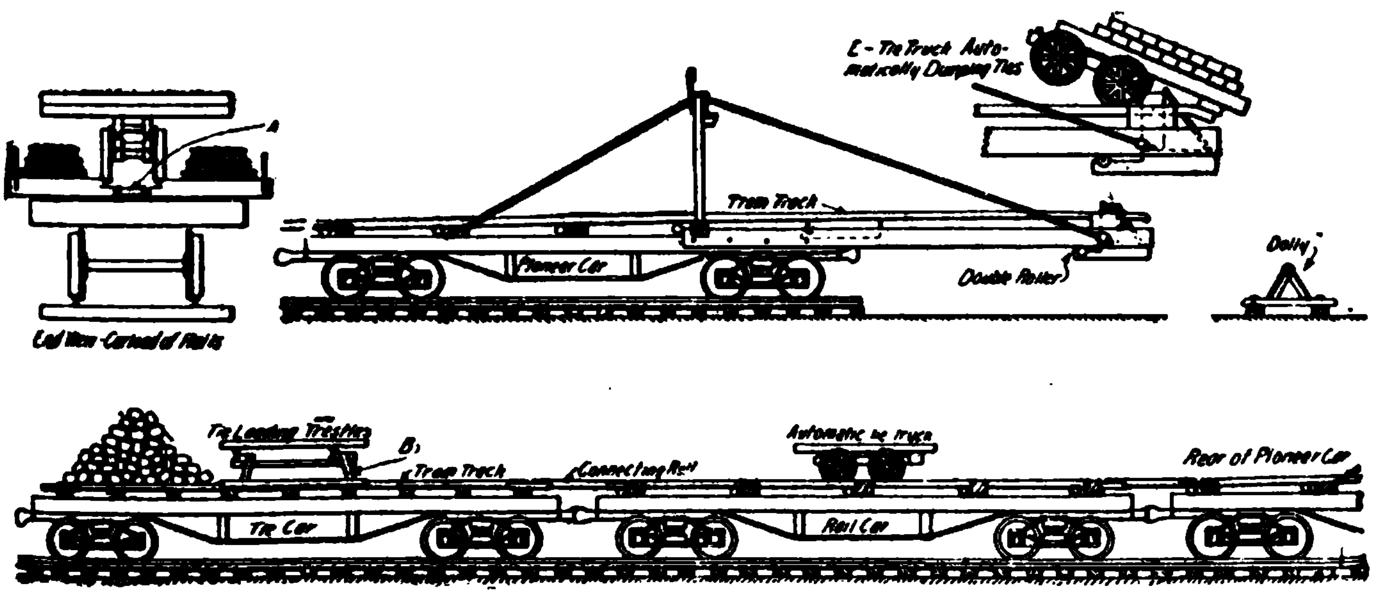
brackets which support the tie trams at the rear stand above the level of the car floor, about knee high, while those at the front end are suspended below the level of the car floor. The sections are connected up continuously forming an incline rollway the whole length of the train, over which the ties and rails are pushed to the front, to be lifted and placed on the roadbed by the track-layers. The rollway for forwarding the rails is arranged on one side of the train (left-hand facing the front) and that for the ties on the other side. The head car of the train carries a derrick or braced tower supporting stays for the shoot or end section of the tie rollway, which is extended beyond the car thirty-five or forty feet. The rail tramway extends ahead of the car 8 feet. On this car, called the 'Pioneer Car' or 'Pilot Car,' are carried the tool boxes and the spikes, bolts and splices for each train-load of material. The spikes and bolts are usually carried in a large box (called the 'Pig Trough') 7 feet long suspended at the head end of the car crosswise the track, about hip high. As the ties and rails are placed in position two strappers and 4 spikers quickly fasten each pair of rails, placing only two bolts in each splice and spiking only the center and quarter ties. The train advances one rail length at a time, the locomotive engineer at the rear taking signals from a man posted on top of the frame on the pilot car. The work of completing the splicing and spiking is attended to in rear of the train, only such work being done in front as is necessary to make safe for the train to pass. The splice bolts are not fully tightened, and it is also quite commonly the practice to place only half the ties in advance of the train.

"The ordinary and most convenient rate of laying track

with this machine, when full tieing ahead is 1½ miles per day. The force required at this speed includes 40 to 45 men with the machine and 22 to 28 men behind the train, the ordinary distribution being about as follows: In front of the machine, 6 or 8 tie carriers, 1 tie liner, 1 chute man, 6 or 8 rail carriers, 2 bolters, 2 nippers, 4 spikers, 1 foreman; on the train, 2 men unloading rails, 2 men pushing rails, 14 to 16 men handling ties; behind the train, 2 tie spacers, 8 to 12 spikers, 4 to 6 nippers, 3 bolters, 1 spike peddler, 4 men lining track, 1 foreman. With larger crews 1¾ to 2 miles of track can be laid each day. In the construction of the Washington County R. R. in Maine, in 1899, a crew of 110 men working with a Holman machine laid 10,300 feet of track, fully tied and spiked, in 9 hours. On the Pacific extension of the Great Northern Ry., in 1891, the average speed with a Holman machine for 82 short days during the winter was more than 1½ miles per day, and in 25 days the average speed was 2 miles per day; the best record was 140 stations, or 2.65 miles one day."

THE HARRIS MACHINE.—"The Harris Track-Laying machine consists of ordinary flat cars fitted up with a roll-way for forwarding the rails and a tramway for a push car or truck on which the ties are run out to the front. Five 6x8-in.x11-ft. timbers or switch ties are laid across each car and spiked fast, and on these is laid a tram track of ordinary rails. On the old machines (which went out of use in 1900) the gage of this tram track was 8½ feet, but on the machines of later designs the gage is only 2 feet, and the track is laid along the middle of the cars. Betweeen the rails of this track, and on a level with base of rail, there are cast iron rollers 15 inches long, on which the rails for track-laying are

pushed to the front. On the cars which carry the rails the cross-timbers are framed out at the middle and the rails of the tram track are depressed to bring the top of rail flush with the tops of the timbers. This arrangement permits the supply rails, which are carried in piles on either side of the tram-way, to be easily slid or rolled onto the rollers. Only the cars loaded with rails have the roll-way, and these cars are, of course, placed ahead of the cars, loaded with the ties. On the cars loaded with the ties, the tram rails are laid on top of the cross-



HARRIS TRACK-LAYING MACHINE.

timbers and alternately between these long ties or timbers there are 8 feet ties to afford close supports for the truck-loading horses or 'trestles,' to be described presently. The gaps in the tram-track, between the cars are closed by short pieces of rail having the bottom flange cut off at each end so that the web may be dropped between splice bars bolted to the ends of the fixed tram-rails on the cars. Allowance is made in the length of the short connecting rails for slack between the cars. On the front car, the tram-track is extended twenty

feet ahead of the car and is held up by truss rods carried over a framed bent 10 or 12 feet high and anchored at the back of the car. The ties are piled across the tram way and the spikes, bolts and splice bars are chinked into spare space on the rail cars. The cross-timbers which project over the sides of the car carry a running-plank on either side for the men to stand upon while loading the ties. It also affords a foot-way for the men pushing the tie truck and a place for the rail men to step aside while the loaded tie truck is passing.

ROBERTS TRACK-LAYING MACHINE.

"The ties are not loaded upon the tie truck direct, but are first placed crosswise on a pair of portable wooden horses or 'tie-loading trestles' stood parallel with the tram track on either side. These tie horses each have a top piece or upper frame carried on links which is raised four inches before the ties are placed upon it. After a truck-load of ties has been placed

across the horses the empty track, which is 2 inches lower, than the tops of the horses in their raised position is run between the horses and under the pile of ties, at the same time automatically disengaging a latch which holds the load of ties in the raised position. In this manner the load is caused to drop 2 inches onto the track, the top pieces of the horses dropping 2 inches further clear of the load and out of the way of the movement of the same. The truck, as thus automatically loaded, is pushed to the front and the work of loading the horses

By the courtesy of the publishers, the Engineering News Publishing Company, the subject-matter regarding "The Six-Chord Spiral" in this volume is taken from a book by that title by J. R. Stephens, C. E., and likewise we are indebted to the same publishers for quotations from "Railway Track and Track Work" by E. E. R. Tratman, C. E.

forward and at the end of the tram-way is run again chocks or stop-blocks. The tram-car body is made in two parts, the upper of which slides between guides, over the lower part on rollers, so that when the car is brought to a stop at the end the load is shifted forward 30 inches, causing the car to overbalance, tilt forward and dump itself, throwing the ties crosswise on the roadbed. The car is then righted and run back for another load, while the rails which had been spliced and lying on the pilot-car are run ahead off the car onto a portable dolly about 30 inches high standing on runners, on the ties, about

feet ahead of the car and is held up by truss rods carried over a framed bent 10 or 12 feet high and anchored at the back of the car. The ties are piled across the tram way and the spikes, bolts and splice bars are chinked into spare space on the rail cars. The cross-timbers which project over the sides of the car carry a running-plank on either side for the men to stand upon while loading the ties. It also affords a foot-way for the men pushing the tie truck and a place for the rail men to step aside while the loaded tie truck is pass-

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:ies are not loaded upon the tie truck direct, first placed crosswise on a pair of portable horses or 'tie-loading trestles' stood parallel tram track on either side. These tie horses e a top piece or upper frame carried on links raised four inches before the ties are placed After a truck-load of ties has been placed

across the horses the empty track, which is 2 inches lower, than the tops of the horses in their raised position is run between the horses and under the pile of ties, at the same time automatically disengaging a latch which holds the load of ties in the raised position. In this manner the load is caused to drop 2 inches onto the track, the top pieces of the horses dropping 2 inches further clear of the load and out of the way of the movement of the same. The truck, as thus automatically loaded, is pushed to the front and the work of loading the horses is repeated. The horses stand on runners, and as each truck-load of ties is delivered they are pulled ahead to a new position within reach of the receding tie-pile on the flat-car.

"In starting out to lay track the rails are thrown onto the rollway with a rail fork and pulled ahead to the pilot car by men with tongs or hooks. Here they are spliced and bolted together four rails at a time—that is, two rails in a stretch for each side of the track—using two bolts to each splice, allowing for expansion and putting in the expansion shims. In the meantime the tie truck or tram-car has been loaded and pushed forward and at the end of the tram-way is run against chocks or stop-blocks. The tram-car body is made in two parts, the upper of which slides between guides, over the lower part on rollers, so that when the car is brought to a stop at the end the load is shifted forward 30 inches, causing the car to overbalance, tilt forward and dump itself, throwing the ties crosswise on the roadbed. The car is then righted and run back for another load, while the rails which had been spliced and lying on the pilot-car are run ahead off the car onto a portable dolly about 30 inches high standing on runners, on the ties, about

25 feet ahead of the extended tram-track. Suspended from the cross-timber at the end of the tram-track there is a roller about a foot lower than the rollers on the flat-car, which serves as an intermediate support for the rail between the end of the car and the dolly. The rails are run to a position opposite their place in the track and are then lifted down and heeled into splice-bars fastened loosely to the last rails laid. In laying broken-jointed track the rails on the 'long side' are simply run a half-rail length further ahead on the rollers. As soon as the rails are in place the track is quarter spiked and the train is moved ahead 60 feet.

"The foregoing is known as the method of 'standard 60 feet set-outs' and is the usual way of proceeding to lay two miles of track per day. In this case 34 to 42 men are required with the machine, according to the weight of rail, quality of the ties (soft or hard-wood), efficiency of the men, organization, etc. Of this crew 14 men called the 'top force,' are engaged on the cars as follows: 4 men loading ties, 3 men running tie car, 1 man breaking out rails onto the rollers, 4 men pulling rails with hooks and delivering them ahead, and 2 top bolters. The 'ground force,' or the men ahead of the machine, are distributed as follows: 1 man with tie line, 1 man with spacing pole and marking ties for line rail, 1 spike peddler, 1 man serving splice bars, 8 spikers, 4 nippers, 2 men carrying dolly, 1 'expansion man' (with sledge to drive rails back when necessary), one heeler (who, as a rule, is the foreman of the ground force), 2 bolters and 4 to 6 extra men; or a total of 26 to 28 men. With soft wood ties the 4 to 6 'extra men' are usually dispensed with, and sometimes the force is cut down 1 or 2 more. The usual practice in laying 60 feet 'set-outs' is to half-

tie ahead. If it is desired to work a smaller crew, laying 1 to 1¼ miles per day, the rails are run down singly, or in 30 feet 'set-outs,' the train moving ahead 30 feet at a time; or by using the same force, half-tieing the track and handling single rails in 60 feet 'set-outs,' 1¼ to 1½ miles of track can be laid per day. For fast work, as when it is desired to lay 3 miles per day, a larger force is put on and the rails are handled in spliced sections of 3 each, or in 90 feet 'set-outs' the train then moving ahead 90 feet at a time. In this case 3 dollies are used ahead of the pilot or pioneer car in running the rails to place.

"With the Harris machine the track layers in advance of the train are not divided into separate squads designated as tie carriers, rail carriers, spikers, etc., as in usual practice with other machines. Each truck-load of ties contains the proper number to lay the 'set-out' of rails (30, 60 or 90 feet of track, as the case may be), and as they are dumped the momentum of the truck throws them sprawling ahead over about 30 feet of roadbed. As the rails cannot be laid until the ties are placed, the whole track-laying gang ahead of the car, except the tie-line man, the two bolters, the splice carrier and the 'fiddler' or tie-marker, is first engaged in placing the ties, which is quickly done. The same men then run out the rails and lift them down and then divide up into spiking gangs and make ready for the train to advance. In rapid work the track in advance of the Harris machine is only half tied, the remainder of the ties being dropped off the box or other cars in which they happen to be loaded and which are coupled in behind the tram-way cars. This arrangement saves transferring half the ties to the machine cars.

"Before referring to records of work performed in connection with the use of this machine the difference in the methods of handling the ties on the old and new machines should be explained. On the old machine the tie truck had to be built wide, for the wide-gage track, and it was high enough to straddle the piles of rails on the rail cars. The tie truck for the machine of later design is narrow, running between the rail piles, and it is much lighter and easier to handle than the old device. On the old machine the ties were loaded directly upon the truck, by hand. For rapid work two tie-trucks were used after the train became half unloaded, as then some time was lost in pushing the truck over the increased distance. In that case the hindermost truck was being loaded while the forward one was being pushed to the front and dumped. The rear truck was made somewhat higher than the other, and when they met the load was transferred by sliding the ties on to the lower truck. The automatic tie-loading device of the present machine enables faster work to be done than was possible with the old machine. On the present machine the tie-truck can be shoved forth and back on the run, if need be, stopping only an instant at either end for the truck to receive or dump its load. It is thus possible to keep a loaded tie-truck on the move half the time. At the same time the present machine is more adaptable to the convenience of working a small crew and laying track at moderate speed, when desired. Four to six men can load and deliver ties for laying a mile of track per day; in laying two miles per day seven or eight men are required. Four men can work at loading the horses—two men placing the ties upon the front end of the horses and two more shoving them back and piling them up.

"A seeming drawback with the Harris machine is the necessity for transferring the rails and at least half of the ties to the specially equipped flat-cars. In fairness, however, it should be considered that both rails and ties are frequently shipped in box, stock, or gondola cars, in which case the rails must be transferred, in any event. In the yards, where the cars between which the transfer of material is to be made, can be switched to stand side by side or end to end, the cost of loading the 'machine cars' is but very little more than the cost of taking the material out of the cars in which it was shipped. There is also an advantage in having the material on the machine cars, for as soon as they reach the front there is no delay in starting the work, whereas with other machines, some time is lost in putting on and taking off apparatus. When working with the Harris machine it is customary to rig up as many cars as may be necessary to have in order to keep the transfer gang in the material yard steadily at work while track is being laid at the front. This arrangement should always provide loaded 'machine cars' as they are needed. The equipment of the cars is comparatively inexpensive, as the material required is standard track material and its usefulness for further service in the track is not impaired, except in the case of the framing out of the cross-timbers on the rail cars. The labor of laying the tram-track on the flat-cars and of dismantling the cars after track-laying has been completed is small. The narrow-gage tramway, located as it is along the center of the train, is less distorted in rounding a curve than is the case with a track or devices at the sides of the cars. As a practical test of this matter, one of these machines was successfully used in laying track on the 24 deg. curves of the Montana

R. R., a standard-gage road running out of Lombard, Mont.

"As a matter of record 3.2 miles of track have been laid with this machine (old pattern) in 9 hours. On the Chicago, Kansas & Nebraska Ry. (now Chicago, Rock Island & Pacific Ry.), in 1887 the average record for 132 days with the Harris machine was 2.18 miles of track laid per day, with a total force of 3 foremen and 100 to 115 laborers, including the gang which transferred ties and rails to the material cars. In building the Guernsey extension of the Burlington & Missouri River R. R., in Wyoming, in 1900, a record made with one of the improved machines was 3,750 feet of track laid in 2 hours and 35 minutes. The track was laid with 75 lb. rails and oak ties, and was full tied ahead of the machine. The crew on the cars and ahead of the machine consisted of 28 men, distributed as follows: Ground force, 1 tie-line man, 1 spacing-pole man and tie marker, 1 spike peddler, 1 splice carrier, 1 heeler, 6 spikers and nippers, 2 bolters and 4 or 5 extra men; top force, 4 men loading ties, 3 men on tie-car, 1 man breaking out rails, 2 men pulling rails. The average day's work with this crew, laying by 30 feet 'set-outs,' and full tieing ahead, was 6,000 feet of track per day."

By the courtesy of Mr. John Smith, a railroad contractor of long experience, Mr. Camp gives in his "supplementary notes" the following on the subject of:

"MATERIAL YARDS IN TRACK-LAYING."—"The location of material yards and the handling of the material on new lines depend a great deal on the conditions under which the work is done. It is a very different matter in laying track on some new roads, that is being built in 10-mile stretches, where it is necessary to finish the first

10 miles in order to pay for the grading of the next 10 miles, from what it is on a long road where the work progresses continuously. Then, again, there is the small company that gets only a few cars of rails at a time, and begins to operate its road before it is built. (In this connection I have seen a road put on trains to do local business when some of the track was only half tied and only two or three ties spiked to a rail—track that I would not advise running a construction train over at any considerable speed.) For a road that gets only a little material at a time and is a long time building, and where only a few miles of track are laid each month no special rule can be laid down for placing material yards or for handling the material trains. For short lines of this kind but little need be said about the material yard, except that what little material is to be stored should be unloaded with as much regularity as possible.

"Where long lines are being built the material yard should be planned out in advance, and the material should all be unloaded according to this plan and with the object in view that it will have to be reloaded, probably in a hurry, and that a delay to the track-laying force for an hour will amount to as much as, or more than, the wages of the unloading gang for an entire day. The mistake usually made is at the very first in not providing sufficient room, by laying side-tracks, to hold the material. Never unload any material off from the main line, either the new main line or the old one, and especially the old one. Never unload material off from a side-track on the old main line that is being used to operate the old road. Never unload material off from a Y-track, either old or new. Never unload material into borrow pits or off from a high fill; and, above all things, never unload the

cars just where the freight train happens to set them, unless it is the proper place. Never send a young man out from the engineer's office to pick up a few men and get those cars unloaded as quick as possible.' Never send a section foreman on the operative road to unload material for the construction or engineering department unless you tell him what you want done and how.

"In level country a satisfactory material yard can be easily planned and quickly and cheaply laid out. The number of tracks and their location will, of course, depend upon the conditions at hand, but have at least two side-tracks. It is well to have at least two side-tracks on the same side of the main line, about 12 feet centers for about 300 feet, when the outer track should swing out farther away from the first. At least one of the tracks should be connected at both ends, and if any of the tracks are to be 'stubs' or 'spur tracks' (which, for temporary use, are about as good as any), the switches should be at the end opposite from the direction in which the track is to be laid—that is, if the road is to be built towards the west, the switches should be at the east end of the yard. As many tracks should be laid as may be necessary to hold all the material that may be on hand at a time. Temporary tracks can be laid with about 12 ties to a rail, and should be surfaced up only as much as may be necessary in order to prevent the rails from being bent. In other words, don't go to the expense of laying a full tied, full spiked, full bolted and surfaced track for a temporary one.

"In unloading the ties pile them at right angles to the track and in not more than two piles on one side of the track. Do not carry them away off, 25 to 100 feet from the track, and do not pile them up in crib-work style, half

one way and half the other. This is sometimes done with the idea of letting the air get at them to dry them out. Rails should always be unloaded lengthwise of the track, and do not unload one car-load 'here' on a couple of ties and another car-load 'there.' I saw, in one instance, 85 lb. rails piled up 10 or 12 feet high, with every other layer at right angles to the track. The cost of unloading them must have been ten times as much as it would have been to have done it right. It took twenty men to load them and it required twice as long to do it as it would have taken ten men if they were unloaded properly. Rails should not be unloaded and piled up close to the track when there is plenty of room, but as far out from it as possible without going beyond the point where a 30-foot rail can be used for a skid to unload and reload them. By doing this the piles can be made about 50% higher than if the rails are piled close to the track, and they can be reloaded in half the time with a smaller force than if they are piled close to the track. Four men will skid up rails from this pile about as quickly as ten or twelve men will load them when they are close to the track. Angle bars as well as spikes and bolts could be unloaded near the rails. A cribwork of ties with a floor of ties or crossing plank about two feet above the track should be made and the kegs unloaded on this. If the material yard is on a grade, put the spikes, etc., at the down-grade end of the piles of rails, so that after a car is loaded with rails it can be started with a bar and run down opposite the 'trimmings' (spikes, bolts, and angle bars). I have seen a few very nice examples of this arrangement.

"I might say that a well arranged material yard is something that is seldom seen, and that, except on the long western lines where men have learned from ex-

perience, material is seldom unloaded correctly. One great mistake, for a small matter, is to place kegs of spikes or bolts on the ground and a thousand feet or more from the rails. I might explain in this connection, even if partly by repetition, that each car of rails should be 'trimmed' when loaded; that is, put on all the angle bars for the rails and usually all of the spikes, bolts, and nut locks necessary for them. The exception in the latter case is where a 'spike car' is used in connection with the track-laying. When the last method is practicable it is about the best, in my opinion, the spikes for the 'back-work' then being carried on a separate car and distributed from this car as may be required. At one end of this same car there should be carried crossing plank and surface cattle guards when the track force is putting them in. What I mean by properly unloading spikes and bolts is that they should never be rolled into borrow-pits or be placed several feet below the level of the track; and they should never be unloaded directly on the ground as the dampness caused by rain, etc., will rot the kegs and rust the bolts. The practice of unloading them low down, off a fill, will also cause the kegs to be broken, so that they cannot be reloaded. Always build a platform with a cribwork of ties about half the height of the floor of the car. It will pay, as it saves breaking the kegs in unloading upon it, they are easily reloaded, and moisture of the ground will not affect them. It is my observation that many men unload track materials with only one idea in mind, and that is to get them off the cars with the least amount of work and trouble and to unload every car wherever the train happens to leave it. For example, in a material yard I have in mind, the spikes and bolts were unloaded at the west end of the material side-track,

while the rails were unloaded at the extreme east end of the yard, one-third of a mile from the spikes, with 30,000 or 40,000 ties piled up along the track in between them.

"All material loaded in the material yard should be loaded properly. When curved rails are being laid they should be curved before loading them to go to the front; and do not forget to curve just enough 'short rails' for them, and do not load the short rails all on the bottom of the car under the rest of the curved rails; place them on top, as it is then easier to get at them at the front; otherwise it is necessary to 'dig' for them when wanted. In laying right and left-hand rails, that is, using a certain side for the 'running' side, as when laying old rails, for example, arrange them on the cars so that they will unload properly. Where the Harris track-laying machine is being used they may be loaded on the right and left-hand sides of the cars, but for other track-laying machines, where the rails are all run forward on one side of the train, it is necessary to load the rails for one side of the track on one car and the rails for the other side of the track on another car, alternating the cars loaded with right and left-hand rails. It is then always necessary to bring out the cars in pairs.

"Personally, one of the best material yards I ever saw was at Fremont, Neb., in 1887, where the material for more than 100 miles of track was piled up. We laid this track by contract, and in only one instance was the 'front' delayed for failure of the prompt delivery of the material to the last side-track, and, as a rule, we laid more than two miles of track per day. An excellent illustration of modern practice in handling material for long stretches of track-laying, especially in the west, was afforded in the methods employed by the Burling-

ton & Missouri Railroad in the Guernsey extension, in 1899 and 1900. The same practice was also employed not only on previous extensions of this same Company, but on other western roads where there was considerable work to do from one point. The material yard on the Guernsey (Wyo.) line was located at Alliance, Neb., the point where the new work started. When the work of laying track started there were vast quantities of ties unloaded and piled up, not promiscuously here and there, but all in one place, along two or three 'tie-tracks.' The rails were unloaded along both sides of a track used only for that purpose. The man who unloaded them did so with the idea that it would be necessary to again load them, and he did it right.

"On this extension (as is the practice on most of the western roads in laying new track) the telegraph wire was brought up to the end of the track every night and an operator was employed so that all reports and orders could be sent in daily. The speed of track-laying was about 1¼ miles per day. The supply train left the material yard at Alliance each evening at about 7 o'clock, carrying material for the next day's track-laying. The selection of the late hour for leaving was to give opportunity to send in special messages by wire late in the day and have the things ordered brought out to the front the same night. In making up this train the cars loaded with the material for the next afternoon's work were placed ahead, with the cars carrying material to start the work in the morning coupled in at the rear of the car. The purpose of this arrangement was to save switching at the farthest side-track, or the point where the material was left, as the car-loads of material for the morning's work were then pushed in at the rear end of the side-track,

in position for 'first out' in the morning, leaving the other division of the train on side-track to be taken out after noon. This arrangement of running the supply trains at night also afforded the best economy in the use of cars, as the cars unloaded at the front during any certain day could be returned to the material yard in time for reloading early the next morning. The ballasting of the track followed close upon the track-laying, so that the material trains were able to make good speed."

BALLAST AND BALLASTING.—This subject, in section 2, under the heading of Maintenance of Way, is treated at length, but, in connection with the laying of ties and rails it may be as well to quote Mr. Camp again, who says:

"The grade for top of rail in ballasting is indicated by stakes about four feet from the rail at one side of the track, opposite every full station and wherever there is a change of grade. These stakes are set after the track is laid. The stake is driven or sawed off to bring its top to grade. If the foreman in charge of the work is experienced at raising track it is useless to set stakes closer than 100 feet apart except where there is a change of grade; and there is no necessity, either, for setting stakes both sides of the track."

RAISING THE TRACK.—Concerning this, he says: "A jack is a better tool for raising track than a lever, because it requires only one man to operate it, whereas a lever usually requires three or more; the jack can also lift through a greater vertical height without changing, and it does not throw the track out of line so much when raising with a lever. If the roadbed is soft, so that the jack sinks in too much, it may be stood upon a piece of plank. Using the level board, the rail is raised to surface

opposite each rail grade stake, and then at the joints and centers, blocking them to place, or shovel-tamping if the ballast is at hand. It is an advantage to have ballast on hand in sufficient quantity to tamp the tie ends, because blocking will settle when the train comes on and the track will have to be raised again, besides, it is not alto-

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TRACK JACKS

gether desirable to leave blocks, stones, etc., under the track so near the bottoms of the ties. With rails of heavy section the stiffness of the rail will usually hold the quarters to surface if the joints and centers are supported. On track laid with rails of light weight a quarter now and then will sag and require raising to surface. In a high lift, light splices are in danger of being bent by taking

hold of the rail at the joint. It is better in a case of this kind to take some point two or three feet to one side of the joint as the raising point. Track usually settles as soon as the jack lets go, and allowance should be made accordingly. It is a good plan to raise every joint somewhat higher than the point to which it would naturally settle back so that it will stand striking down. The usual arrangement is to have a man carry a 16 lb. sledge along and strike down on the tie tamped. In this way a good surface can be had without taking so much pains with the raising, and the ballast under such ties gets hardened to a considerable extent by being struck down.

"It is well to raise and hold the rails on both sides to surface before tamping the ends of the ties, because where one rail has been raised and the tie ends have been tamped, when it comes to raising the rail on the opposite side the rail first raised will rise with an eighth to a quarter as fast and leave the ties which have been tamped bearing only at their ends, with a clear space under the tie at the rail seat. The side last tamped will then hold up better than the side tamped first, and the track will settle more on one side than on the other; but this is not liable to happen where neither side is tamped until after both sides have been raised and held. Unless the side first raised be blocked, and that directly underneath the rail, it will rise a little with the second side when it is raised, as just explained, and after the track is leveled across or elevated it will be somewhat higher than the grade stakes. There is no objection to this excess, because it provides an allowance for settlement and does not usually leave the surface of the side first raised uneven; should it do so occasionally, a few strokes from the sledge on the high ties will usually put it right.

Some make it a practice to set the jacks outside the rails and raise both sides of the track at the same time. Where the lift is high this is a good plan.

"The man who sights the rail should be at least 60 feet back of the point which is being raised, so that his eye can catch a good stretch of rail between. It is well to designate each point which is raised opposite a grade stake by placing a pebble or chunk of dirt on the rail, for it is an aid in sighting other points on the rail with reference to it. One man can sight for two jacks—one at raising points, the other at raising centers. About the utmost speed attainable in raising track at one place would be had by using five jacks; one crew with jack and level-board could put both rails to grade opposite grade stakes; a man behind, sighting for two jacks, could follow and place one rail, that is one side, to surface; and behind him on the opposite side, a crew with jack and level-board could raise the joints, and another jack with a man to sight for it could be used in putting up the centers. The best sighter should be put on the side which is in the advance. It requires a little genius as well as judgment to sight rails well and rapidly." * * * *

"When the rails are out of true the ties appear to form the elements of a warped surface. On curves the rails are sighted along the inside of the curve.

"Track tangents should be raised and tamped level transversely. There are those who claim that a train will run more steadily on straight line if the rail on one side is about 1/4-inch lower than the other than it will on track which is level transversely. This claim is based on the idea that the wheel flange on the lower side will follow the rail instead of moving first towards one side and then towards the other, as it does on track which is level

transversely. But the coning of the wheels would not in all probability allow this steadiness of movement on straight line, and if it did, more power would be expended in hauling the train, because if the same wheel-flange followed one rail all the time, either one or both wheels would have to slip a little almost constantly.

"In ballasting new track, it is desirable, especially when working a large crew, to have the track where raising is in progress entirely free from passing trains. In case the ballast must be hauled from the rear, the best plan, if practicable, is to first unload ballast along the track for several miles in sufficient quantity to tamp the ties outside the rails; on fills where the track is to be raised 6 inches or higher there is not usually room for more material than this. Then everything is ready to begin with part of the crew to raise the track and tamp the ties outside both rails; this will hold up a train without settling to hurt, and the train should follow to haul what ballast is needed to complete the work. The remainder of the crew should follow the first party and tamp the ties between the rails, line the track and fill it in."

TAMPING BAR.

TAMPING.—"Except where broken stone or slag is used for ballast the shovel is the best tool for tamping new track. Tamping bars are not effective in such work. The tamping bar is intended to be used only where ballast can be confined in a small space, such as is found between the bottom of a tie and a hard bed, when the lift is small. In raising new track, where the lift is usually several inches, the ballast must necessarily be put in loose; and it can become hard and compact only after time and by pressure from trains running over it. The range of action of a tamping bar is only an inch or two in depth

below the bottom of the tie at the most, and consequently it is a waste of time to attempt to harden several inches of ballast under the tie with such a tool when the ballast between the ties is in a loose condition. The shovel does just as good work and is far more rapid. In shovel tamping, the gravel or other ballast is first shoved under the tie with the shovel blade, and then crowded, the latter effect being produced by putting the foot on the shoulder of the blade and driving it under the bottom of the tie, at the same time prying backward a little on the handle, thus enabling the lower edge of the blade to pry forward and crowd. Before placing the foot upon the blade, ballast should be filled in between the ties as high as an inch or two above the tie bottoms, so that a fulcrum may be had for the back of the shovel blade to pry against. The thin edge of a shovel blade, even when new (being only about 3/32 in. thick), is not worth much for a rammer; it is, therefore, the prying and ramming combined which crowds or tamps the ballast under the tie, but principally the prying. This is the reason it is so important that ballast between the ties should all the while be kept somewhat higher than their bottoms and that the edge of the shovel blade should penetrate under the lower corner or edge of the bottom face instead of against the side of the tie." * * * * * * * * * * *

"In starting out at tamping, the foreman, who by all means should at some time have worked at shovel tamping himself, should take a shovel and show each man individually how it is done." * * * * * * * *

"Men should be given to understand that as soon as a tie is properly tamped the work on that tie should cease, since there is not the slightest necessity for tamping against the side of it; that is to say, above the edge of

the bottom face; that as soon as one is through tamping under the bottom of one tie further effort can most profitably be expanded under the bottom of the next tie ahead."

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"Most kinds of dirt ballast can not be well tamped with the shovel blade. Cast ends are sometimes provided for shovel handles, so that the tamper may take the edge of the blade in his hand and use the handle as a rammer and in some kinds of dirt ballast they do pretty good work. A tool called a puddle is sometimes used for this purpose. It resembles very much a tamping pick with the pick end of the tool cut off near the eye.

"Stone and slag ballast are tamped with tamping picks. Each tamper works by himself, stooping over the tie and driving the rock into the space underneath it. In order to do this work uniformly, more or less care must be exercised, for, if not mindful, one may, in striking with a tamping pick easily wedge parts of the track up above its proper surface. The material is first thrown into the track loosely and pushed under the ties with shovel, and then thoroughly packed with the tamping picks. After a few days the track should be carefully resurfaced, taking out the rough spots, tamping the raised ties and filling in and dressing off. As already stated, rock to be broken for ballast is sometimes thrown into the track and broken up there. This is not a good plan to follow, however, since the ballast is liable not to be broken finely enough to the proper depth, unless the rock be thrown in a piece at a time. It gives the men a chance to break the material finely on the top and leave larger pieces underneath where they cannot be seen. The ballast if broken on the spot ought, therefore, to be broken up on the shoulder, outside the track. It should be thrown in with

forks rather than shovels, since with the latter it is difficult to handle rock ballast lying on the ground without taking up some dirt with it; and of course it is desirable to keep rock ballast clean in order to prevent the growth of vegetation and the churning of ties.

"Shovel tamping is done on both sides of the tie simultaneously. Outside the rails two men work together, on opposite sides of the same tie; between the rails four men—two on each side of the tie—usually tamp together. Ties should be well tamped directly underneath the nail seat. This can always be done to best advantage by getting the tool in there at the start. A shovel blade must be thrust in cornerwise in order to do it, and such cannot be done after the tie has already been tamped farther out toward the end; or farther in toward the middle, if tamping be done inside the rails. When tamping either outside or inside the rails one should aim to tamp the tie directly underneath the rail from that side. It is an easier matter to tamp the ties at this point when using a tamping bar or tamping pick than when using a shovel. When tamping new track for the first time, the middle of the tie may, without ill effect, be tamped as firmly as the ends, but after that the middle should never be tamped quite as solidly as the ends." * * * * * * * *

Regarding Ballasting Cars.—"The Rodger ballast-car of improved design is convertible into a flat-bottomed gondola car. The car of improved design is similar to the old car, but having the addition of removable sloping ends and foldable longitudinal sections attached to the intermediate sills, which may be swung over to form a tight flat-bottom gondola car, overcoming the objection to the old-style Rodger ballast-car, namely, that it was not available for ordinary freight service, although exten-

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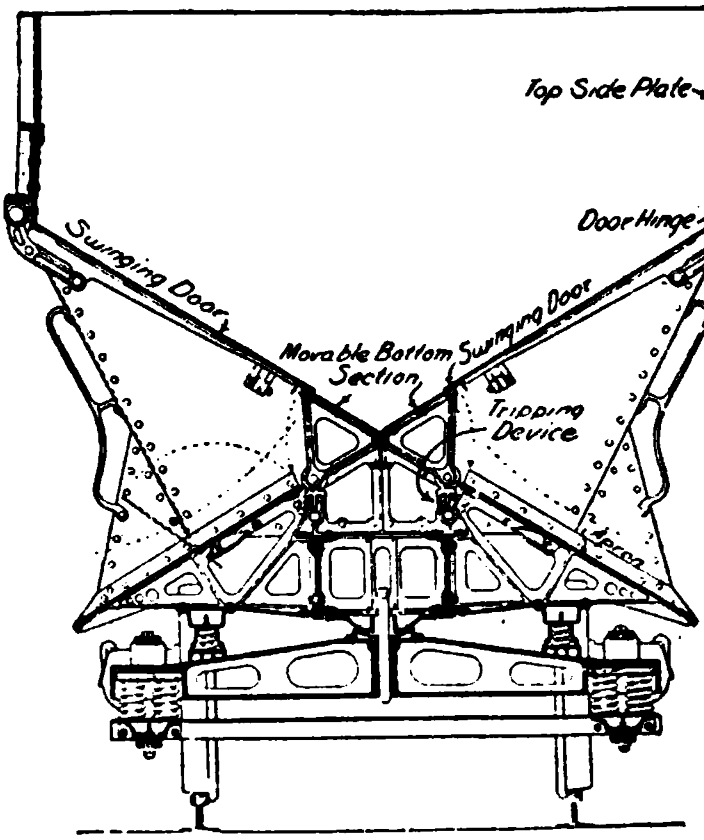
ner by a crew of eighteen men in one-half day, the men being employed, for the most part, in pushing the slag down into the hoppers with bars. After raising the track to grade and tamping it with slag that material was leveled down even with the bottoms of the ties, and cinder ballast for filling was dumped in the same manner.

"Another very well-known car for hauling either ballast or filling material is the Goodwin car, in use on a large number of roads. This car is made to dump either



GOODWIN DUMP CAR.

at the side or from the center or from both outlets at the same time. The car as now built is constructed entirely of steel and iron. As shown in the cross-sectional view, the body of the car is built upon two plate-girder sills, 21 inches apart. These girders are 18 inches deep at the middle and 9¼ inches deep at the ends. The space between the sills is left clear for dumping the load

between the rails, and from each sill there is an apron or floor inclining downwards. The two ends of the car are connected by stop side plates 18 inches deep and the car is divided at the middle by a transverse bulkhead, so that either of the two compartments can be dumped independently of the other. To the top side plate on each side of the car in each compartment, there is hinged a

GOODWIN DUMP CAR WITH SWINGING DOORS OPEN

swinging door, which, when the car is loaded, rests upon the projection of a movable section in the bottom of the hopper. This bottom is composed of two narrow movable sections hinged to a longitudinal shaft. Each bottom section is held in position by a tripping device, by means of which the said movable section on either side of the car may be released, when it swings downward, inclining toward the apron, thus releasing the swinging door and permitting the discharge of the load. The apron is

hinged along its middle line (longitudinally), so that the upper portion can be swung upward, as shown by the broken lines at the left side of the figure. When the upper section of the apron is set in this position and the swinging door released, the latter strikes against and is held by a spring on the raised portion of the apron and the contents of the car are discharged between the sills and inside the rails of the track. The dumping devices are arranged to be operated either by hand or by compressed air. Hand dumping is accomplished by the wheel at the end. When equipped for pneumatic dumping an air cylinder is attached to the end of the car, on the outside, beside the hand wheel. This car can be made to discharge half of its load on one side and half on the other; or half in the center and half on the outside; all on one side, or all in the center, as is desired. The car is 35 feet 11 inches long over the end sills, 8 feet 10 inches wide over all, and the extreme height above top of rail is 8 feet 6 inches. The carrying capacity is 80,000 to 125,000 pounds, or in volume, with the load heaped, it amounts to about 29 cubic yards. The ends of the car are of wood construction, but in later design the ends are constructed entirely of steel. These cars are constructed with a view to turning them to service for carrying coal, ore, grain and other bulky freight. For grain service the car is provided with an adjustable steel top for protecting the grain from the weather, and for carrying coke there is a top crate which enlarges the capacity to 37 cubic yards."

Lining.—Continuing Mr. Camp says: "After the track has been tamped, and before it is filled in, it should be lined. It can be easier thrown before it is filled in than afterward, as there is then not so much material to

GOODWIN CAR WITH END BRACE.

hold the ties, and besides, the rail is more free to align itself farther from the point at which it is thrown, thereby lessening its tendency to kink and require throwing at more frequent intervals. The foregoing applies to track in most kinds of ballast, but in stone or slag ballast the track should be lined before it is tamped the last time, because when track is thrown on freshly placed ballast of these kinds the pieces of stone will roll and raise it out of surface. As a guide in throwing the track to the center stakes, a tack is driven in the middle of the gage, or it is notched at that point. The gage is then placed across the rails at each center stake and the track is thrown to bring the mark on the gage vertically over the tack in the stake. It is well to place pebbles or other small objects on the rail at such points to designate the place. The crew then goes back and throws the joints, centers, and quarters if need be, to line with the rail at these designated places. Six men will usually be a large enough force to handle it easily, and in some cases four will be sufficient. They should all throw together at the word, with a rather steady pull or heave, not trying to jerk too quickly. At some places where there is a short kink the rail must be held at one place while throwing it at another, so as to avoid throwing out of line the portion which is so held."

FILLING-IN AND DRESSING.—"After the track is lined it is filled in and dressed off. The manner of filling in depends a good deal on the quality of the ballast. Track in broken stone, ordinary gravel, cinder and like kinds of ballast should be filled in full, even with the tops of the ties inside the rails, but not over the tops. For a distance of six inches inside the rails, however, and from there on out to the end of the tie, the ballast should be

just enough lower to nicely clear the rail base. If the ballast be even with the rail base, sand or dirt will be sucked in between it and the tie face, as the rail springs up and down under trains, and in winter the flange of the rail between the ties will lie in a frozen rut which will be a hindrance to shimming and other kinds of work which must sometimes be done. The expansion or heaving of the ballast is also liable to lift the rails from the ties and start the spikes. Beyond the ends of the ties the ballast should be shouldered out full depth a distance of at least 8 inches, and better if 10 or 12 inches. Ballast banked against the ends of the ties helps very much to hold the track in line. It also keeps the ground from freezing that much deeper in the winter, and in case of derailment gives some aid to the wheels and protection to the ties. The portion just outside the ends of the ties is usually called the ballast shoulder. From the top of the shoulder the ballast may be sloped off gradually toward the ditch or edge of fill; broken stone ballast is usually sloped off more abruptly—something like 1 to 1, say. If too much ballast has been left during construction it may remain to be used in repairs later on, but no material should remain piled in a ditch or in a cut.

"In all kinds of loose ballast through which water soaks away readily little attention need be given to dressing the material with a view to draining the water off the top; but in dirt ballast, and, to some extent in sand ballast also, the conditions are different. In those cases, the ballast must be so dressed that it will run all water possible off the top and keep it from getting underneath the ties. The only thing which makes dirt a practicable ballast is good surface drainage. Dirt and sand ballast should be rounded up two or three inches higher than the tops

of the ties in the middle of the track, covering the ties, over a strip about 3 feet wide, and then sloped down to the bottoms of the ties at their ends, passing 1 or 1½ inches under the rail base. The standards of some roads require that between the rails the ties shall be covered as far as a line three inches from the rail base, from which point the ballast shall be sloped down to the bottoms of the ties at their ends, 'care being taken to leave an opening under the rail for drainage.' Outside the ends of the ties the surface should slope away gently out over the shoulder. On quite a number of roads, one of which is the Illinois Central, it is the practice to fill in and dress off cementing gravel ballast in this manner; that is, to heap it up in the middle of the track and slope it down to the bottoms of the ties at their ends. Cementing gravel does not pass water freely, and it is so difficult to work that much labor is saved by leaving the ends of the ties uncovered, so that they may be readily opened out for tamping.

"There are several objectionable effects from the banking of ballast inside the rails, two or three of which it may be well enough to remark upon. Where ballast is dressed in this manner there is always a tendency to center-binding of the track. In the first instance, as elsewhere stated, the ballast or earth under the exposed ends of the ties is not as well retained as it is under the middle of the track, where there is a full depth of filling. When the ground is thawing the frost leaves from under the ends of the ties before it does the middle of the track. The effect of this condition is inequality of support and a slight rocking of the track, which causes it to settle out of surface. Nevertheless, in the qualities of ballast under consideration, the advantages obtained by covering the

ties in the middle of the track outweigh the disadvantages. Aside from the superior drainage effected, the heap of ballast in the middle of the track assist materially in holding the track in alignment. When heaping the filling in curved track it is usual to crown it on the outer side of the center line, which brings the highest point of the filling nearer the outer than the inner rail; otherwise it might not be possible on track highly elevated to make the filling slope both ways.

"When dressing off filling for the first time, except in dirt ballast, it is not worth while to spend any time at work intended merely to make a neat appearance, because the track will soon settle and have to be raised. At the first dressing merely 'cuff' it over roughly with the shovel, but after the track has been put in good surface the second time, it may be dressed off more carefully. In dressing off stone ballast, it puts a 'finishing touch' on appearances to lay a margin of stones to line on the shoulder, parallel with the rails, but opinions regarding the utility of such work are likely to be influenced by personal tastes."

QUANTITY OF BALLAST REQUIRED.—"To fill in track properly with ballast, between the ties and for a foot outside the ends, even with the tops of the ties, requires about 16 cubic yards of material per 100 feet of single track. For every inch below the bottoms of the ties, about 4 cubic yards of ballast is required per 100 feet of track. For double track, 13 feet centers, filled full between the tracks evenly with the tops of the ties, about 2 1/5 times the above amount will be required for filling down as far as the bottoms of the ties—that is, about 35 cubic yards per 100 feet; for ballast below this point, double the figure, or 8 cubic yards per 100 feet per inch in depth."

CONSTRUCTION ACCOUNTS.

Railway companies with highly organized departments maintain a distinct bureau to make accurate itemized records of everything pertaining to construction accounts. Minute classifications of all expenses are kept, every item being charged to its proper sub-division in such classifications.

In a general way, but perhaps not so minutely subdivided, construction accounts are required to be kept when the company may not have such a highly developed and complex organization.

Therefore the practice of rendering accounts and the particulars regarding how items should be classified and charged, which follows, may be of much assistance to those unfamiliar with such details.

BILLS.

Every official incurring indebtedness on account of the company will request that bills covering the same be rendered promptly; upon receiving such bills they will be carefully examined, and, if found correct, so certified in ink by the official, who will sign his full name and title; they will then be forwarded to the assistant engineer who, after approving the same, will forward them to the division engineer for voucher.

Bills should state all the facts as clearly as the nature of the case will permit, giving all items, quantities, prices and dates in full; if bill as rendered does not give all information necessary to a proper understanding of the

transaction, the certifying official should add sufficient explanation to make it fully understood.

All bills should reach the division engineer's office not later than the seventh day of the month, and such record kept of them by certifying officials as to preclude the possibility of their certifying a duplicate bill for the same account.

Bills covering purchases by the purchasing agent, or shipments from stock, will be forwarded by the general storekeeper, or division storekeepers, to the engineer in charge of the work, who will write the distribution on face of bill, certify to the receipt of the material and return bill promptly.

VOUCHERS.

All vouchers will be made in division engineers' offices, certified by them, and forwarded promptly to the chief engineer. They should be forwarded daily as made up, and should all reach the chief engineer's office by the sixteenth. They should be numbered consecutively, commencing with No. 1 for the first January voucher each year.

CASH EXPENDITURES.

Officials supplied with company funds should understand that the money is only to be used to make small payments for supplies in the field, or other expenditures for which circumstances make it necessary to pay cash. Wherever possible bills should be certified and forwarded for voucher in the usual manner.

For all cash payments, receipts should be taken, giving the residence of signer and date of payment. If for sup-

plies, the receipt must give different items in detail; when for board or lodgings, the exact time for which charge is made, and name of the individual boarded or lodged.

These receipts must be sent in to assistant engineer promptly at the close of mouth, with list of same accompanying, and after examination forwarded to division engineer for voucher.

Officials must be careful to observe the limitations placed upon making cash payments, as it is found there is a tendency to make unnecessary payments in this manner, instead of forwarding bills for voucher and payment by the treasurer.

TIME RETURNS.

Time returns will be made out by each official in charge of a party, and, after being certified, forwarded to the assistant engineer in charge of the work in time to reach his office on the first day of the month. After being approved they will be forwarded to the division engineer so as to reach his office by the third of the month.

The name and occupation of every employe will be returned on the time book, and when an employe has not worked a full month, the days actually worked must be shown.

Particular care must be taken to spell each man's name correctly on the return, and to write the name clearly; neglect to do this is inexcusable.

When time made by employes is omitted from return of current month, it will be entered on succeeding month's roll with notation showing from what month's roll it was omitted. All possible care must be exercised to prevent such omissions.

Time of men who are paid a monthly rate will be stated in months or fractional parts thereof, using actual calendar days of the month in which the labor is performed, as 28, 29, 30 or 31, as the case may be; time of employes paid a daily rate will be stated in days and hours.

For gangs of laborers and section men, time books must be kept and sent in at end of month as prescribed for time returns.

PAY ROLLS.

Pay rolls will be made up from time returns and time books in the division engineer's office and will be forwarded to the chief engineer not later than the fifth of the month.

Time books will be sent to the chief engineer with the rolls; when the latter are audited they will be sent back to the division engineer for filing.

DISCHARGE CHECKS.

Employes leaving the service of the company should be paid in full at time of leaving or as soon thereafter as practicable. For this purpose a Discharge Check will be given the employe for the current month.

When an employe has been paid by discharge check (which will only be issued to men leaving the service) his name will appear on time return in the usual manner, with the notation "D. C." and number of same. Parties using discharge checks will be held responsible for their correctness, and for the proper notation being made on time return. Any overpayment will be charged to them. Before the returns are forwarded the Discharge Check stub should be carefully checked with same.

Be careful and see that the month in which service is performed is always correctly stated; if Discharge Check be given for omitted time in one month, to appear on pay rolls for another month, note the fact prominently in red ink on the face of the check.

Discharge Checks cannot be issued after time returns have been forwarded, except by authority of chief engineer.

DEDUCTION FROM PAY ROLLS.

Amounts due the Railway Co. will be deducted from pay rolls; no orders will be required, and deductions of this kind will take precedence over all others.

Deductions will be made for board from section and other laborers boarding in section houses, boarding cars or boarding camps; it will not be necessary to take orders. Orders should, however, be taken for all board deductions from other employes.

When it is necessary or desirable to protect parties who supply merchandise to employes, deductions will be made from same upon presentation of proper accounts.

Pay rolls will show to whom deductions from each employe are payable, and a deduction roll will be made containing name, address and amount due each party to whom deductions are payable.

ASSIGNMENT OF WAGES.

Assignments will not be honored unless made for full amount due.

When a party claims to hold an assignment of wages and notifies the officers, under whom the assignor is employed, the holder of the assignment will be required to

produce it; if found good in law, notation should be made in ink on pay roll, opposite name of assigning employe, in column provided for receipt, as follows: "Assigned to" giving name of assignee, and date of presentation of assignment; but no deduction will be made on pay roll. If assignment is presented before pay roll is prepared, a record should be made, and proper notation made on pay roll when prepared; if presented after pay roll has been forwarded, the auditor of disbursements should be advised by wire. The treasurer must be notified by wire of every assignment as soon as presented.

After an assignment is made, the assigning employe has no further interest in the wages thus assigned so far as this company is concerned, and payment will be made to assignee only; and to him only upon surrender of assignment to paying officer, who, upon payment thereof, will take assignee's receipt and attach assignment thereto.

Assignee will receipt thus: "John Smith, by Wm. Jones, assignee" and not individually.

GARNISHMENTS.

When service of garnishment or attachment is made on an officer, agent or employe of the company, he should at once telegraph the treasurer, division counsel and division engineer, stating the nature of the case and giving the name of the plaintiff and defendant, and also the occupation and location of the latter. He should forward papers served by first train mail to the division counsel for the district in which the action is brought.

CONTRACTORS' ESTIMATES.

Promptly at the close of the month each resident engineer will make on the prescribed form detailed estimates, by stations, of all work done by contractors. They will be written in copying ink, and forwarded to the assistant engineer, who, after checking and approving will consolidate the same on the proper forms and forward in duplicate to the division engineer for voucher.

Forms as provided for the purpose will be forwarded in duplicate to the chief engineer with voucher covering the estimate.

As contractors' estimates are generally payable on the twentieth of the month, it is absolutely necessary that they should reach the chief engineer not later than the tenth, and, to secure this, prompt and accurate work by all concerned is necessary.

Separate forms must be made for the work of different contractors.

No information will be given to contractors or subcontractors in reference to their estimate until the same shall have been approved by the division engineer, and no information in regard to a final estimate until approved by the Chief Engineer.

FORCE ACCOUNTS.

Whenever work is required to be done which is not covered by the prices herein mentioned, the Chief Engineer of the Company shall give a written order for the doing of the same. Nothing shall be deemed extra work, however, which can be measured or estimated under the provisions of the contract.

All claims for extra work or material must be presented to the Chief Engineer of the Company for allowance at the close of the month in which it was done or furnished, otherwise all claims therefor shall be deemed absolutely waived by the contractor, and the Company shall not be required to allow or pay for the same.

APPROXIMATE ESTIMATE OF EXPENDITURES.

On the first day of every month, each assistant engineer will send to his division engineer an approximate estimate of the expenditures on his work in the preceding month. Give amounts to nearest hundred dollars, and after this manner, viz.:

Company Bills and Traffic Charges	$1,200
Pay Rolls	1,000
Bills	5,600
Estimates	4,800
Total	$12,600

Note.—Contractors' estimates should include retained percentage, if any, and if more than one contractor on the work, give estimate of each separately. Include all bills sent in to division engineer for voucher in preceding month. Give any extraordinary expenditure as a separate item.

The approximate estimate of assistant engineers will, after being checked by the division engineer, be telegraphed to the chief engineer not later than the third of the month, each piece of work being given separately.

DISTRIBUTION.

All bills, pay rolls and estimates must be distributed by the certifying official before being forwarded, by notation on face of bills, and by a memorandum accompanying estimates and pay rolls. Distribution to buildings must show the particular structures and their location.

Engineering expenses are not to be so distributed, the object being to keep record of the labor and material expended directly upon each building. Treat in above manner stations, section houses, freight houses, water tanks, pump houses, turntables, engine houses, important bridges, etc.

When voucher is prepared the distribution will be condensed on face of voucher. Use numerals when indicating the distribution on voucher. The following is the established construction distribution:

I. ENGINEERING EXPENSES.

To this account should be charged the salaries and wages of all persons employed in engineers' service, including clerks, janitors, teamsters and cooks; the cost and repairs of field, office and pocket instruments, drawing boards, blueprint apparatus, office furniture, stationery boxes, tents, temporary quarters for engineers, camp equipage, cooking utensils, stoves, cost of hire of animals and vehicles; provisions and forage for men and animals, including board, hotel bills, traveling expenses, stable bills; rent, heating, lighting, cleaning and repairing engineers' offices; stationery and other contingent expenses of engineers.

LAND.

2. RIGHT OF WAY AND STATION GROUNDS.

To this account should be charged the cost of land acquired for roadbed (of necessary width conformity to depth and slopes of excavations and embankments), station and terminal grounds; also the cost of land purchased for ingress or egress to and from station ground; salaries and expenses of counsel, right-of-way agent, and of engineer and assistants when especially engaged upon such matters; stakes used to denote right of way limits; expenses of appraisals, or of juries, commissioners or arbitrators in condemnation cases, cost of removal of buildings when upon right-of-way station or terminal grounds, but not included in property purchased; stationery supplied right-of-way agent, engineers and assistants, engineers' instruments, etc., when used for such purposes; commission paid outside parties for purchase of properties for these purposes; cost of plats, abstracts, notarial fees, recording deeds, etc.

Note particularly account No. 3 as regards cost of property purchased, but not required for the operation of the road.

3. REAL ESTATE.

To this account should be charged the cost of all land purchased by the railway in excess of that actually required for road bed, station, or terminal grounds, or other specific purposes, including all expenses incurred in connection with such purpose as enumerated in account

No 2, "Right of Way and Station Grounds." A portion of the cost of land purchased outside right-of-way for borrow pits or waste banks should be charged to this account.

Note.—The amount to be charged to Real Estate should be an estimate of the saleable value of said borrow pits or waste banks after completion of the road.

4. GRADING.

To this account should be charged the cost of clearing right-of-way, station grounds or otherwise, and grubbing, as required by specifications; the cost of grading roadbed and station grounds whether excavation or embankments; dressing slopes of cuts and fills; reconstructing pikes or roads; ditching roadbed; berm ditches; cost of material taken from borrow pits, haul if allowed; rent of equipment used in hauling material; amounts paid for privilege of borrowing material or making waste banks outside of company's right-of-way or station grounds; ditches for water ways not specially required by right-of-way agreement, in which case cost would be properly chargeable to account No. 2. This account also includes retaining wall and other masonry or rip-rap for the protection of embankments, cuts and slopes; cribbing or bulkheading built to protect the tracks or embankments along the seashore or banks of lakes and streams, including the cost of cribs, breakwaters, wing dams, or other devises constructed to change the direction of the current of a stream to prevent the washing out of the bank; grading for road crossings.

5. TUNNELS.

To this account should be charged the cost of tunneling, including such timber as may be used for centering, packing, etc.; cost of stone, brick, cement sand, lime, salt, piles, timber, spikes, nails, braces, concrete, etc., used in the construction or lining of same; cost of labor preparing or securing the same, scaffolding, cofferdams, and pneumatic caissons; cost of soundings and machinery, pumps, engines, etc., used for such work. This account does not include grading or surfacing the roadbed, or cost of the track through the tunnel.

6. BRIDGES, TRESTLES AND CULVERTS.

To this account should be charged the cost of all bridges and trestles erected to carry tracks over streams, ravines, streets or other railroads, and culverts, both substructure and superstructure, including fire protection. This account should include abutments, piers, pier filling, supports, draw and pier protection, machinery to operate drawbridges, masonry ends and wing walls for culverts, cost of inspection of bridge material either at shop or site of structure, cost of tests, of wing dams, cribs, or icebreakers for the purpose of regulating the current of a stream or breaking up ice-jams before reaching a bridge; cost of excavating channels at bridges; also labor and material used in painting structure.

In case "false work" is furnished by the company for erection of bridge superstructure, the cost of same should be charged to this account, and when removed the value of the material removed should be credited to this account and charged to the account benefited.

Note.—The cost of ties, guard rails and other track material used on bridges and culverts is chargeable to account Nos. 7, 8 and 9.

Note.—When bridges or culverts of a more expensive class are erected in place of old ones, only the difference between cost of the new structures and original cost of the old ones will be charged to "Improvements." Credit "Improvements" and debit "Operating Expenses" with actual cost of old structure, and when actual cost cannot be ascertained, make estimate based on prices prevailing at time the structures were built.

TRACK.

7. TIES.

To this account should be charged the cost of all cross, switch, bridge and other ties laid in the main track or tracks, sidings, spurs, gravel and repair track; in tunnels, depots, shop and other yards, shops and other buildings, etc.; on turn-tables, wharves, piers, track scales, inclines, bridges, trestles and culverts to and from coal chutes, coal pockets, fuel and water stations, etc.; also the cost of inspection, loading and unloading, and any process of preservation.

8. RAILS.

To this account should be charged the cost of rails and guard rails laid in the main tracks, sidings, spurs, gravel and repair tracks; in tunnels, depots, shop and other yards, shops and other buildings, etc.; on turn-tables, wharves, piers, track-scales, inclines, bridges, trestles, and culverts to and from coal chutes, coal pockets, fuel and water stations, etc.; also the cost of inspection, loading and unloading.

9. TRACK FASTENINGS.

To this account should be charged the cost of spikes used for laying rails, and of fish and tie-plates, splice and angle bars, chairs, rail braces, bolts, nuts, nut locks or washers used in connection with same; also cost of inspection, loading and unloading.

10. FROGS AND SWITCHES.

To this account should be charged the cost of all frogs, switches and switch material, including switch stands (throw or lever), frog guard rails, crossing frogs and timbers, bolts, etc., used in foundations or base of same.

11. TRACK LAYING AND SURFACING.

To this account should be charged the cost of distributing, laying, spacing and lining ties; cost of laying, spiking and jointing rails, surfacing and lining track, including the adjustment of rail to the proper elevation, and labor of placing frogs and switches; cost of track tools, including shovels, picks, track-jacks, crowbars, levers, spiking mauls, gauges and wrenches; cost of putting in ballast; service of engines, cars and crews distributing track material, and rental of such equipment.

12. BALLAST.

To this account should be charged the cost of all ballast, whether of broken stone, slag, gravel, other material especially provided for this purpose; also the expense of loading, hauling, and unloading alongside of track, and rent of equipment.

STRUCTURES.

13. STATION BUILDINGS AND FIXTURES.

To this account should be charged the cost of all material and labor expended on station buildings and outhouses in connection therewith, including cost of platforms, sidewalks, excavation, foundation, drainage, water, gas and sewer pipes and connections, steam-heating apparatus, stoves, electric light and power fixtures, including wiring for same, grading and putting ground in order after building has been finished; electric bells, elevators, and all other material, furniture, or fixtures used to complete the building; wells for water supply of station; also salaries and expenses of architects.

Note.—This account should include the cost of similar buildings on docks, wharves and piers, when used for station purposes.

Note.—The class of buildings considered as coming under the head of Station Buildings are those used in connection with the handling of traffic, such as Passenger Station Houses, Freight Depots, Track Scales and analogous structures.

The cost of all structures not properly chargeable to Accounts Nos. 13 and 26, inclusive, should be charged to Account No. 32, Miscellaneous Structures.

14. ENGINE HOUSE AND TURN-TABLES.

To this account should be charged the cost of all roundhouses (including cinder and drop pits), and turn-tables, heating, lighting and power plants, platforms, sidewalks and outhouses in connection therewith.

This account should include amounts paid when erected by contract, labor and material when built by company, preparing grounds before and clearing up same after construction, foundation, painting, excavation for and lining turn-table pit, and of cinder or drop pits inside or outside of roundhouses; foundation for turn-tables; loading, unloading and placing turn-table in position; levers, stops and machinery for operating turn-table; sewerage system, connection with water supply system and wells. This account does not include the cost of tracks laid in connection with roundhouse or turn-tables.

15. ENGINE AND CAR SHOPS.

To this account should be charged the cost of all buildings to be used as shops (including transfer tables); heating, lighting and power plants, platforms, sidewalk and outhouses in connection therewith; oil houses, sand house, store houses for company's material, scrap bins, etc.

This account should also include amounts paid when erected by contract, labor and material when erected by company, preparing grounds before and after clearing up same after construction; foundation, painting, sewerage system, connection with water supply system and wells. This account does not include the cost of tracks laid in connection with these buildings.

16. SHOP MACHINERY AND TOOLS.

To this account should be charged the cost of all new machinery and additional tools placed in any of the shops, including foundation for same; loading, unloading

and placing machinery in position. It must not include any machinery or tools purchased to take the place of those that have worn out or destroyed.

17. WATER STATIONS.

To this account should be charged the cost of the material and labor expended in the construction of water stations for the purpose of supplying locomotives with water, including cost of windmills, pumps, boilers, pump-houses, tanks, tubs, tank foundations, track foundations, track tanks or troughs, engines and all fixtures and pipes, standpipes or penstocks and connections; wells, dams and reservoirs or cisterns, rip-rapping reservoirs and spillways; also tools used in the work This account must not include waterworks, wells, etc., exclusively for supply of stations, hotels, tenements or section houses, which should be charged to the appropriate accounts.

18. FUEL STATIONS.

To this account should be charged amounts paid under contract for, or the cost of all labor and material expended in the construction of coal platforms, coal sheds, coal pocket chutes, woodsheds and racks, and all machinery or appliances necessary to equip them for service. This account includes inclines at fuel stations (except the cost of track laid thereon), tipple cars, buckets, cranes for handling same, elevating machinery, gasoline or other engines for operating same, dumping machinery, all appliances for weighing coal in pockets and opening coal pockets.

19. FENCING RIGHT-OF-WAY.

To this account should be charged the cost of all material and labor used in construction board, wire, rail, hedge, stone, or other fences along the right-of-way or limits of roadbed; but no charge should be made to this account for fences constructed around stock yards, fuel stations, station grounds shops, and on other properties outside of right-of-way, which should be charged to their appropriate accounts.

20. SNOW FENCES AND SNOW STRUCTURES.

To this account should be charged the cost of all structures erected exclusively to protect road or buildings from snow.

21. STOCK YARDS.

To this account should be charged the cost of all labor and material expended on stock yards, including facilities for feeding, watering and weighing.

22. CROSSINGS, CATTLEGUARDS AND SIGNS.

To this account should be charged the cost of all labor and material used in constructing farm, country road or street crossings at grade; overhead bridges, cattleguards and wings and all track signs, crossing gates and watchhouses at crossings, but not cost of grading.

23. INTERLOCKING OR SIGNAL APPARATUS.

To this account should be charged the cost of interlocking or signal apparatus complete, when built by contract. If built by the railway company the cost of labor

and materials, including all levers, racks, wires, pulleys, semaphores, semaphore signals, ground signals, posts, material in box troughs and other fixtures, tower, foundation for same, and all other work necessary to complete it.

24. DOCKS, WHARVES AND COAL BUNKERS.

To this account should be charged the entire cost of docks, wharves, ferry or other landings, inclines to transfer steamers, and coal bunkers and machinery; including grounds and riparian rights, dredging of slips, piling, filling cribs, pile protection, building cofferdams, pumping or bailing water, masonry walls or filling, etc., and all expenses incurred in the construction of these structures, except the cost of tracks and buildings thereon.

25. TRANSFER BOATS AND BARGES.

To this account will be charged the cost of boats and barges. Renewals, repairs and operating expenses of boats in construction service are not chargeable to this account, but will be charged to the accounts benefited by the service, this account being designed to represent the cost of the property only.

26. SECTION AND TOOL HOUSES.

To this account should be charged the cost of all labor material expended on all buildings for use of track and bridgemen, including buildings for storing and protecting hand and push cars, tools, etc.

27. GRAIN ELEVATORS.

To this account should be charged the cost of ground on which elevator is located, cost of foundations, elevator buildings, conveyors, fixtures, and machinery complete; and material, labor, transportation, and other charges incidental to construction. This account does not include the cost of small storage elevators at way stations, which are considered to be station buildings.

28. STORAGE WAREHOUSES.

To this account should be charged the cost of ground on which storage warehouses are located, and cost of buildings, machinery, etc., complete, when built by contract; if built by the railway company, the cost of ground, material, machinery, fixtures and labor, transportation, and all other expenditures incidental to construction.

The buildings herein referred to are not the ordinary freight warehouses or stations where freight is received for shipment, etc., but warehouses in which merchandise is stored, and which the railway company or others operate as warehouses.

29. ELECTRIC LIGHT PLANTS.

To this account should be charged the cost of all labor and materials, including cost of transportation, used to put in operation either arc or incandescent light plants, such as dynamos, engines for running dynamos, wire constituting lines, glass globes, carbon or arc lights, carbonized filament for incandescent lights, poles, hangers

for lights, insulators, and every expense incidental to the erection of a plant. When it is necessary to erect a building for an electric light plant, the entire cost of same, including ground, should be charged to this account.

30. ELECTRIC MOTIVE-POWER PLANTS.

To this account should be charged the cost of ground on which electric-power stations are located, and the cost of erection of power houses and car sheds, including all expenditures for labor and material, stationary engines, boilers, and machinery, pumps, condensers, foundations, and settings for steam plants; generators, foundations and settings, switchboard and lighting apparatus for electric plants; current conductors, including poles, wires, and labor for overhead work, third rails, fastenings for same and labor laying same, with costs of inspection, loading and unloading; feed wires, track bonding, and grade crossing cut-outs and all other expenditures connected with the installation of plants intended to generate and distribute electricity for motive power, including transportation.

31. GAS-MAKING PLANTS.

To this account should be charged the cost of all labor and material, including cost of transportation, used to put into operation a gas-making plant complete. The cost of ground on which the plant is located should also be charged to this account.

32. MISCELLANEOUS STRUCTURES.

To this account should be charged the cost of structures of every character, including cost of materials, labor, and all incidental expenses connected therewith,

which are permanent or a betterment to the property and enter into the cost of road, and which are not otherwise herein particularly referred to, and for which no account has been provided, the object being to designate one general classification to which may be charged the cost of all minor structures; and in this way avoid increasing the number of general accounts.

33. TELEGRAPH LINES.

To this account should be charged the cost of newly constructed telegraph and telephone lines, including poles, wires, billets, insulators, instruments, and all other materials used, also labor employed in the construction work, and cost of all tools used.

MISCELLANEOUS.

34. TRANSPORTATION CHARGES.

To this account should be charged local freight, passenger and express charges over the railway and branches.

35. OPERATING EXPENSES AND EARNINGS.

To this account should be charged all expenses, not herein designated to be charged to other accounts, for transporting construction material over road being constructed and for rental of equipment; also expenses for operating road for traffic while in charge of construction department, including payments for personal injury, stock killed or injured, or other damage caused by operating for traffic. This account will be credited with the amounts received for transportation of such traffic.

36. CONSTRUCTION EQUIPMENT.

To this account should be charged cost of all equipment for construction purposes, including steam shovels, pile drivers, stone derricks, stone crushers, iron, hand, push and velocipede cars and tunnel machinery, but exclusive of boats. Renewal, repairs and expenses are not chargeable to this account.

37. EQUIPMENT AND MAINTENANCE OF SECTIONS.

To this account should be charged the cost of all tools, hand and push cars necessary to equip new sections. Also the cost of maintaining sections after the road has been turned over to the Operating Department, but maintenance of track still left with the Construction Department.

38. GENERAL EXPENSES.

To this account should be charged expenses of incorporation and all contingent expenses, which are not proper charges to engineering, such as taxes, printing and engraving bonds, etc.

39. INTEREST AND DISCOUNT.

To this account should be charged construction interest, discount on securities sold, interest on loans effected and on notes issued for construction purposes or overdue payments to contractors or other creditors, and discount, interest and exchange on other commercial paper issued for a similar purpose. Premium realized from sale of bonds, stock or other securities for a specific work should

be credited to this account. Discount or premium realized from sale of bonds, stock or other securities for a specific work should be applied to such work.

40. LEGAL EXPENSES.

To this account should be charged the amount of all attorney's salaries, fees and expenses, and all other incidental legal expenses incurred during the process of construction of a road, except when the expense can be charged directly to the account for which it is incurred.

TRACK LAYING REPORTS.

The number of feet of main track laid every day must be telegraphed to the chief engineer and division engineer in the following manner:

"—————— Division, main track laid Jan. 10, 1904, from station 626 to station 640, fourteen hundred feet."

A daily record of all track laid must be carefully kept, with every blank properly filled in. This report will be forwarded to division engineer by first train, who, after checking and making record of same, will forward to chief engineer.

INSTRUMENT REPORTS.

All persons in charge of instruments, live stock, tents, etc., will make a monthly report of same on the form provided, following printed instructions on blank. These reports will be written in copying ink and forwarded to assistant engineer, who will forward all for his work, in one package, to division engineer. After being checked in division engineer's office, an impression copy will be taken and all forwarded in one package to the chief engineer.

Instruments which become unfit for service should be forwarded to the chief engineer, with a card attached, stating the defects in full.

Instruments must be properly cared for, and any damage resulting from negligence will be charged to the part at fault. Surplus instruments should be sent in to the division engineer.

REQUISITIONS.

Assistant engineers will make all requisitions through the division engineer.

A copy of the requisitions will be sent to assistant engineer to advise him as to what material has been ordered for his work, and to enable him to check the same upon receipt.

Purchases of subsistence stores and camp equipment will be made by assistant engineers under the supervision of the division engineer.

For all other articles, requisitions must be made as above specified, except in cases of emergency to avoid delay to work, when material may be ordered by wire, such orders being confirmed at once by requisition, with notation "confirming telegram of this date." Should urgency be so great as to require immediate local purchase, authority for such purchase must be obtained by wire.

RECEIPT OF MATERIAL AND DISTRIBUTION RECORD.

All material must be carefully checked with invoice immediately upon receipt, and a record of it entered in the "Material Book" of the prescribed form as provided, showing date received, car initials and number, way bill number, quantity and description of material, name of

shipper, date of invoice and amount, date that the invoice is certified and returned, amount of traffic charges, and date expense bill is certified and handed back to agent. Any shortages must be reported by letter accompanying the invoice. A smaller book or blotter will be used in entering receipt of the material, from which the Material Book will be posted.

A distribution record, of the prescribed form as provided, will be kept, containing a complete record of construction cost in proper numerical order, including both labor and material, under the accounts numbered 1 to 40.

In this record will be entered the following:

1. The bills of material required for each special structure or bridge, and all general construction items of rails, cross ties, angle bars, bolts, fencing, etc., not included in special bills of material.
2. The number of the requisition covering each item of material.
3. The partial or complete receipts of material applying on such requisition.
4. The reference to the page of the Material Book from which such receipts are posted.
5. The cost of the material received as ascertained and posted from the invoices of same.

Enter under proper accounts engineering expenses, expenditures for right-of-way, real estate, and all other expenditures that go to make up the complete cost of the work.

Accounts should be posted daily, checking complete receipts of each item in red ink. Partial receipts should be entered under head of remarks, noting page number of Material Book and amount of invoice, until completed and properly counter-checked.

This record must show at all times the exact relation between the requirements of the bill of material and the receipts to date, as this information is most important.

At the conclusion of work forward the material and distribution records to the division engineer, who will furnish to the chief engineer a complete abstract of cost of each special structure, including large bridges, containing cost of each class of labor or material, but omitting itemized details of same.

Where, under the terms of contract, contractors are required to care for material, the records will be kept in precisely the same manner. Material clerks are required to give contractors every assistance in caring for material and full information at any time as to the purpose for which any material is intended, and will see that no material is diverted from the purpose for which it was intended, without authority of assistant engineer.

All material must be unloaded promptly, and no material will be borrowed, loaned or sold except by authority of the chief engineer.

TRANSFER OF MATERIAL TO OPERATING DEPARTMENT.

When work on branch lines, or on special improvements is finished, all material left over will be inventoried by the engineer in charge, and loaded and shipped to division store, or otherwise, as directed. This inventory must show in detail location, quantity, description and percentage of value as compared with new material of like kind. It should be forwarded promptly to the division engineer, thence through the office of the chief engineer to the general storekeeper, who will arrange to give the work proper credit.

INVENTORIES.

At the end of each month each assistant engineer, resident engineer, or other official having property of the railway company in his charge, will make out a full inventory of it and forward same to the chief engineer through the division engineer.

The value of this inventory depends upon its being made promptly, and showing, in detail, what property the railway company owns, where it is located, and what it is worth. Division engineers will see that the above instructions are followed, and that the inventories are complete in every particular.

INSURANCE.

All buildings, important bridges, trestles and other structures liable to damage from fire will be reported to the chief engineer for insurance immediately on completion. Make these reports in tabulated form, as follows:

Description of buildings for insurance on the

Place	Use	Station Opposite Center	Distance and Direction from Main Track	Dimensions Ground Plan	Number of Stories	Kind of Structure	Kind of Roof	Value Other Remarks

Make special mention of engines, tools and machinery in shops, and of pumps, boilers and water supply pipes in pump houses.

Description of bridges for insurance on the

No. of Bridge	Station at ....end	Miles from	Character	Length	Value and Other Remarks

Give piers and abutments as separate items. Include cost of rails in the value column. Bridges costing less than $400.00 need not be reported.

WORK TRAIN SERVICE.

Work trains will be controlled by assistant engineers or such other official as they may designate.

Trainmen will be furnished on request of the division engineer.

The transportation rules of the railway company will govern all lines under construction.

Locomotives and enginemen will be furnished on requisition made through the chief engineer's office.

All enginemen and trainmen will be carried upon the rolls of the assistant engineer.

Requisitions for engines and cars will be made through the chief engineer's office, specifying the purpose for which required.

All conductors will make daily reports of all cars handled by them.

At the close of each month assistant engineers will forward all reports to division engineer with a statement covering the same.

At end of every month each assistant engineer will make a report to his division engineer of all cabooses, boarding cars, water tank cars, tool cars, etc., used on his work during the month, giving car numbers, dates between which used, purpose for which used, and whether used by company or contractors.

From this report the bills of rental against construction department and contractors will be made up in the division engineer's office.

Construction material must be promptly unloaded and cars returned at once.

Under no circumstances must foreign cars be used in work-train service, nor must any cars be used as cabooses or boarding cars except those furnished for that purpose.

COMMERCIAL TRAFFIC DURING CONSTRUCTION.

The province of this department is to construct new roads, not to operate them, and they are to be turned over to the operating department as soon as practicable.

The object of these instructions is to relieve this department from handling money, and place the responsibility of properly collecting and accounting for revenue arising from transactions of commercial business in the hands of the officials of the railway company, to whom such work belongs.

The accounting department will see that such earnings are duly credited to construction account.

Time cards will be arranged by assistant engineers with as much reference to convenient transaction of commercial business as is consistent with the economical handling of construction work.

Officers and employes are to handle no money collected for transportation of freight and passengers except as herein provided.

As soon as commercial business is likely to be offered, the assistant engineer shall notify the division engineer, who shall request the division superintendent under whose jurisdiction the branch will pass when completed, to nominate agents and operators, subject to approval by the chief engineer and the proper officials.

The chief engineer will request the general traffic manager to publish freight and passenger rates.

A traveling auditor will be sent to install, instruct and bond station agents.

The division engineer will ask the division superintendent to furnish train crews.

The men so nominated and installed will be in the employ of and paid by construction department.

They will be directly under orders of the assistant engineer in everything, except collecting and remitting money, making way-bills and reports, and keeping accounts. In these matters they will be under orders of and comply with instructions given by the accounting department and by the treasurer.

Conductors shall furnish the assistant engineer with duplicate reports of all collections to permit a check on same.

Neglect to comply promptly and fully with rules of these officials will be cause for dismissal.

Standard printed rules and regulations in force under operating department defining their duties, will be furnished, and must be strictly complied with.

If express, mail or telegraph services are extended over the branch, agents, operators and conductors will transact the business in conformity with current practice on the adjacent main line.

When assistant engineers deem change of agents, operators, dispatchers, or conductors necessary, due and sufficient notice must be given to the division superintendent.

Agents must not be transferred from station, or given leave of absence until checked out by traveling auditor and substitute duly installed.

The accounting department will provide outfit of stationery and blanks necessary to open new stations.

When no regular trains are run, conductors of work trains will collect, report and remit cash collections as provided in instructions to conductors of regular trains, and all work train conductors will follow same rules.

No person will be allowed to ride on trains without paying fare, unless provided with a pass.

Assistant engineers will make themselves familiar with rules and regulations in force on operating divisions, and see that their agents and conductors act in accordance therewith.

Assistant engineers stand in the same relation to these employes as a division superintendent to his men.

PASSES.

Books of passes will be furnished from the chief engineer's office to assistant engineers for issue to employes traveling on company business.

Passes will not be honored unless bearing written counter-signature of the person authorized to do so, and conductors will decline to honor any pass signed or countersigned "by" or "per" any person.

Passes for families of employes, contractors or employes not traveling on company business, will be issued only on approval of chief engineer.

ACCIDENT REPORTS.

In case of accident on the railway or on the property of the company, resulting in death or personal injury, either to employes or others, employes must telegraph the facts immediately to the division engineer. This telegram must be confirmed by written report on the blank provided for that purpose and forwarded by first mail to the division engineer, who will transmit the same through the office of the chief engineer to the general claim agent.

If the injured employe is allowed compensation for time lost on account of injuries or other payment therefor, release of damages should be taken. Such allowance or payment should be made only on authority first obtained from the chief engineer.

Copy of special instructions issued by the general claim agent relative to use of release blanks will be furnished to engineers on application to the division engineer.

TELEGRAMS.

Messages should be sent by wire only when the mail services will not answer the purpose. There is a tendency to use the telegraph for communicating matters of small importance, simply because there is less care and time involved to the sender in one form than the other.

APPENDIX.

SUPPLIES AND EQUIPMENT FOR FIELD PARTIES.

SUPPLIES FOR 12 MEN, 30 DAYS

(*Or in the same proportion for any number.*)

600 lbs. Flour
50 lbs. Buckwheat flour
50 lbs. Oatmeal
30 lbs. Cornmeal
150 lbs. Sugar
20 lbs. Salt
10 lbs. Baking Powder
2 lbs. Mustard
1 lb. Pepper, ground
1 lb. Ginger, ground
½ lb. Cinnamon, ground
¼ lb. Allspice, ground
100 lbs. L. C. Bacon
150 lbs. Bacon
30 lbs. Dried Beef
25 lbs. Codfish
2 cases Condensed Milk
20 lbs. Coffee
20 lbs. Tea
30 lbs. Lard
6 lbs. Yeast Cakes
20 lbs. Stilton Cheese
100 lbs. Beans
60 lbs. Rice

10 lbs. Barley
20 lbs. Soap
1 bottle Lemon Extract
1 bottle Vanilla Extract
10 lbs. Currants
1 box Raisins
1 gallon Vinegar
30 lbs. Evaporated Apples
60 lbs. Dried Prunes or Plums
¼ lb. Nutmegs, ground
1 large box Matches
1 box Candles
1 lb. Lye
60 lbs. Butter
6 bottles Worcestershire Sauce
75 lbs. Canned Corn Beef
60 lbs. Yellow Sugar

Eggs, fresh meat and vegetables as required, if they can be obtained from the farming community.

ENGINEER EQUIPMENT AND STATIONERY.

(*For One Field Party.*)

1 Transit
1 Level
1 Chain, 10 extra links
1 Level Rod, 12 ft.
1 Hand Level
1 Barometer
1 Prismatic Compass
1 Protractor, Celluloid
48 Thumb Tacks
6 Camel Hair Brushes

1 Scale, triangular, 10th inches
1 Straight Edge, 30 in., steel, nickel-plated
1 Drafting Board, 3 ft. by 2 ft.
1 Stationery Chest, 12 in. by 15 in. by 30 in.
1 Solar Ephemeris
1 Boxwood Thermometer
6 Scratch Blocks
12 Blotters
1 Block Vouchers
12 Papers Tacks, 8 oz. tinned
3 quires Wrapping Paper
12 Balls Twine
1 Slab for India Ink
2 Inkstands
4 pads Letter Paper
4 pads Note Paper
4 quires Foolscap
3 Triangles, 10, 8 and 5 in. 30 and 60
1 roll Tracing Cloth, 36 in.
1 Book of Recipes
2 Tin Map Cases, 6x36 in.
1 Steel Tape, 100 ft.
4 Hand Axes and Extra Handles
1 Brush Hook
2 50-ft. Tapes in cases, 2 without cases
1 Stick India Ink
1 pint Combined Writ'g Fluid, in stone bottle
1 small bottle Red Ink
2 dozen Shipping Tags
6 Transit Books
6 Level Books
6 Topography Books
1 Requisition Book

6 Note Books
6 Indelible Pencils
100 Bills
12 2-H Pencils
12 4-H Pencils
12 Lumber Crayons
100 Manila Envelopes, large
100 Manila Envelopes, small
6 Penholders
1 box Assorted Pens
12 Crowquill Pens
1 box Pins
6 Rubber Erasers
50 sheets Cross-section Paper, 10ths
20 yds. Drawing Paper, 30 in. wide
10 yds. Plate A Profile Paper, thick
24 Time Books
1 box Rubber Bands, assorted
2 lbs. Keil in sticks

CAMP EQUIPMENT.

(For One Field Party.)

1 Tent and Fly, 10x12
2 Tents and Flies, 12x14
1 Grindstone
1 Handsaw
1 Cross-cut Saw
1 Alarm Clock
1 bundle Sail Twine and Needles
2 Flat Files for filing axes
10 yds. Toweling

2 Stew Pans
2 Water Pails
2 5-gal. Dishpans
2 large Iron Spoons, 12 in.
1 Soup Ladle
1 Cake Turner
2 Butcher Knives
2 Tarpaulins, 12x12
1 Shotgun and Cartridges
1 Rifle and Cartridges
1 Hammer
2 pair Climbing Irons
2 coils ⅜-in. Rope.
18 Extra Bags
2 Sibley Stoves, sheet iron, with pipe.
1 4-hole Folding Cook Stove and kettles, complete.
3 pieces Pipe, with dampers
12 pieces Pipe, without dampers
2 Whetstones
1 set Pot Hooks
1 Bake Pot
2 nests of Tin Pails
4 Pepper Boxes
4 Salt Dishes
1 Sieve
1 Collander.
2 Can Openers
1 Meat Hook
1 Potato Masher
1 Rolling Pin
1 Bread Board
1 Flesh Fork

1 Biscuit Cutter
18 Teaspoons
18 Tablespoons
18 Knives
18 Forks
2 Washbasins
10 lbs. 10 d. Nails
4 lbs. 4 d. Nails
2 Iron Pots
2 Coffee Pots
2 Tea Pots
1 large Frying Pan
1 small Frying Pan
18 Coffee Cups
24 Tin Plates

MEDICAL EQUIPMENT.

(For One Field Party.)

½ doz. boxes Cooper's Pills
1 lb. Rochelle Salts
1 lb. Epsom Salts
2 bottles Iodoform Gauze
6 rolls Bandages
1 roll Sticking Plaster
2 oz. Laudanum
1 gal. Fly Oil
1 doz. 1 oz. Phials and Corks
3 Surgeon's Needles
1 card Surgeon's Silk
6 1 oz. bottles Chlorodyne

APPENDIX—VERTICAL CURVES.
TABLE OF ORDINATES TO VERTICAL CURVES.

Distance from P.C.	Rate of Change per Station. 0.05	0.10	0.15	0.20	0.30	Distance from P.C.	Rate of Change. 0.05	0.10	0.15
00	0.00	0.00	0.00	0.00	0.00	500	0.63	1.25	1 88
10	0.00	0.00	0.00	0.00	0.00	510	0.65	1.30	1 95
20	0.00	0.00	0.00	0.00	0.01	520	0.68	1.35	2.03
30	0.00	0.00	0.01	0.01	0.01	530	0 70	1.40	2 11
40	0.00	0.01	0.01	0.02	0.02	540	0.73	1.46	2.19
50	0.01	0.01	0.02	0.03	0.04	550	0.76	1.51	2.27
60	0.01	0.02	0.03	0.04	0.05	560	0.79	1.57	2.35
70	0.01	0.02	0.04	0.05	0.07	570	0.81	1.62	2.44
80	0.02	0.03	0.05	0.06	0.10	580	0.84	1.68	2.52
90	0.02	0.04	0 06	0.08	0.12	590	0.87	1.74	2.61
100	0.03	0.05	0.08	0.10	0.15	600	0.90	1.80	2.70
110	0.03	0.06	0.09	0.12	0.18	610	0.93	1.86	2.79
120	0.04	0.07	0.11	0.14	0.22	620	0.96	1.92	2.88
130	0.04	0.08	0.13	0.17	0.25	630	0.99	1.98	2.98
140	0.05	0.10	0.15	0.20	0.29	640	1.03	2.05	3.07
150	0 06	0.11	0.17	0.23	0.34	650	1.06	2.11	3.17
160	0.06	0.13	0.19	0.26	0.38	660	1.09	2.18	3.27
170	0.07	0.14	0.22	0.29	0.43	670	1.12	2.24	3.37
180	0.08	0.16	0.24	0.32	0.49	680	1.16	2.31	3.47
190	0.09	0.18	0.27	0.36	0.54	690	1.19	2.38	3.57
200	0.10	0.20	0.30	0.40	0.60	700	1.23	2.45	3.68
210	0.11	0.22	0.33	0.44	0.66	710	1 26	2.52	3 78
220	0.12	0.24	0.36	0.48	0.73	720	1.30	2.59	3.89
230	0.13	0.26	0.40	0.53	0.79	730	1.33	2.66	4.00
240	0.14	0.29	0.43	0.58	0.86	740	1.37	2.74	4.11
250	0.16	0.31	0.47	0.63	0.94	750	1.41	2.81	4.22
260	0.17	0.34	0.51	0.68	1.01	760	1.45	2.89	4 33
270	0.18	0.36	0.55	0.73	1.09	770	1.48	2.96	4.45
280	0.20	0.39	0.59	0.78	1.18	780	1.52	3.04	4.56
290	0.21	0.42	0.63	0.84	1.26	790	1.56	3.12	4.68
300	0.23	0.45	0.68	0.90	1.35	800	1.60	3.20	4.80
310	0.24	0.48	0.72	0.96	1.44	810	1.64	3.28	4.92
320	0.26	0.51	0.77	1.02	1.54	820	1.68	3 36	5.04
330	0.27	0.54	0.82	1.09	1.63	830	1.72	3.44	5.17
340	0.29	0.58	0.87	1.16	1.73	840	1.77	3.53	5.29
350	0.31	0.61	0.92	1.23	1.84	850	1.81	3.61	5.42
360	0.32	0.65	0.97	1.30	1.94	860	1.85	3.70	5.55
370	0.34	0.68	1.03	1 37	2.05	870	1.89	3.78	5.68
380	0 36	0.72	1.08	1.44	2.17	880	1.94	3.87	5.81
390	0.38	0.76	1.14	1.52	2 28	890	1.98	3.96	5.94
400	0.40	0.80	1.20	1.60	2.40	900	2.03	4.05	6.08
410	0.42	0.84	1.26	1.68	2.52	910	2.07	4.14	6.21
420	0.44	0.88	1.32	1 76	2.65	920	2.12	4.23	6.35
430	0.46	0.92	1.39	1 85	2.77	930	2.16	4.32	6 49
440	0.48	0.97	1.45	1.94	2.90	940	2.21	4.42	6 63
450	0.51	1.01	1.52	2.03	3.04	950	2.26	4.51	6.77
460	0.53	1.06	1.59	2.12	3.17	960	2.31	4.61	6.91
470	0.55	1.10	1.66	2.21	3.31	970	2.35	4.70	7.06
480	0.58	1.15	1 73	2.30	3.46	980	2.40	4.80	7.20
490	0.60	1.20	1.80	2.40	3.60	990	2.45	4.90	7.35
500	0.63	1.25	1.88	2.50	3.75	1000	2.50	5.00	7.50

The preceding table of vertical curves gives the vertical distances from the tangent grade line at the corresponding distances from the P. V. C. or P. V. T. (See first column.)

The distances are to be taken up or down according to the form of the grade angle:

Example:—Given a —0.8 grade meeting a +0.5 at station 103, El. 136.42. It is required to insert a vertical curve having a rate of change of 0.1 per station.

In this case the grade angle or algebraic difference of the two rates will be 1.3 feet.

Hence the curve will be 1.3÷0.1=1300 feet long, or 650 feet on each side of the vertex—then

103—(6+50)= 96+50 P. V. C. El.=136.42+(0.8× 650)=141.62.

103+(6+50)=109+50 P. V. T. El.=136.42+(0.5× 650)=139.67.

From these elevations and that of the vertex the elevations on the grade tangents are computed, using the 0.8 and 0.5 rates, see column 2 of the subjoined tabulation.

Column 3 gives the corrections which are taken from the vertical curve table for a 0.1 rate at the corresponding distance from the P. V. C. or P. V. T.

Column 4 in this case is the sum of columns 2 and 3 and gives the corrected grade elevations.

Intermediate values as for cut-offs, of pile bents, etc., are obtained by interpolation in the vertical curve table, before transferring to column 3 in the subjoined.

Thus for Sta. 104+37, which is 513 feet from P. T., the correction would be between 1.30 and 1.35 in the proportion of 3 to 10, or 1.315.

The tangent grade at 104+37=136.92+(.37×0.5)= 137.105, and this plus 1.315=138.42.

Station.	Tangent Grade.	Vertical Correction.	Corrected Grade.	Station.	Tangent Grade.	Vertical Correction.	Corrected Grade.
96+50 P.V.C.	141.62	Zero	141.62	104	136.92	+1.51	138.43
97	141.22	+ .01	141.23	104+37	137.105	+1.315	138.42
98	140.42	+ .11	140.53	105	137.42	+1.01	138.43
99	139.62	+ .31	139.93	106	137.92	+ .61	138.53
100	138.82	+ .61	139.43	107	138.42	+ .31	138.73
101	138.02	+1.01	139.03	108	138.92	+ .11	139.03
102	137.22	+1.51	138.73	109	139.42	+ .01	139.43
103	136.42	+2.11	138.53	9+50 PVT	139.67	Zero	139.67

Intermediate rates in the vertical curve table may be obtained by multiplying the tabular values for the 0.1 rate by the rate selected.

A 0.25 rate of change in this table is also obtained by interpolation between the 0.2 and 0.3 rates.

Note that the ordinates for the 0.2 rate may be taken directly from any table of squares.

Thus for 470 ft. the square equals 220900 and the ordinate is 2.21 for a .2 rate and 1.105 for a .1 rate. Similarly for 473 feet the ordinate for the 0.2 rate is 2.24.

THE SIX CHORD SPIRAL.

There are two general forms of spirals in common use.

1st: The Track Parabola, in which the deflections from the point of spiral vary as the squares of the distances measured from the same point along the curve.

In the ordinary cubic parabola these distances are measured along the tangent produced.

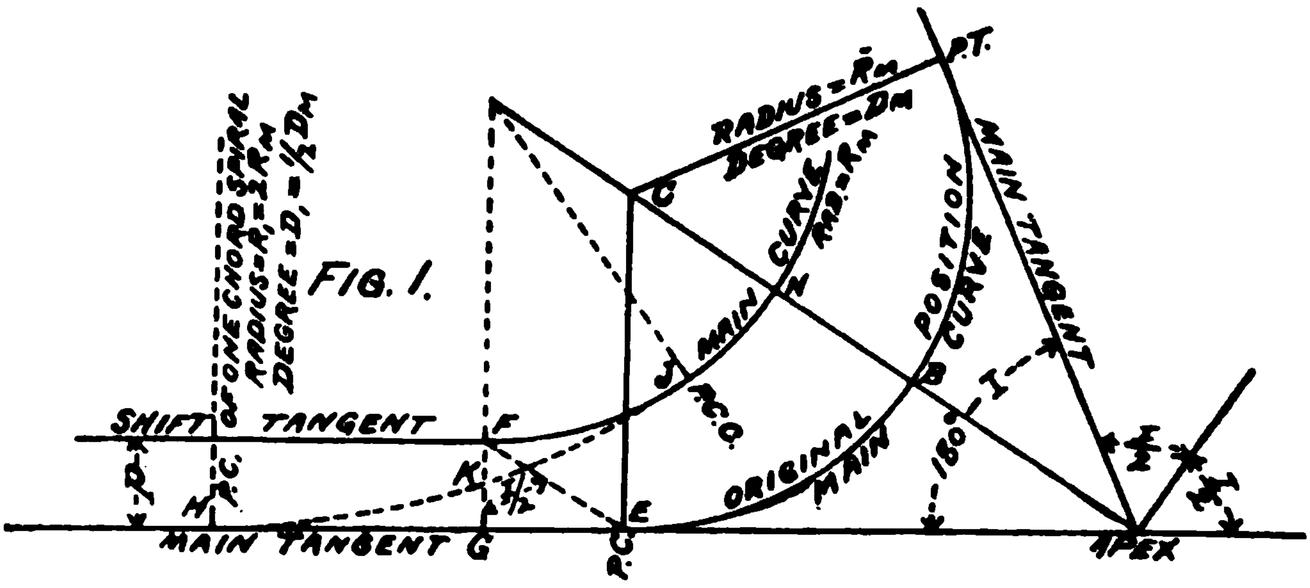
With the track parabola, any given values of R_M and p, Fig. 1, are fitted exactly.

Further, any intermediate point can be set exactly and the instrument being moved up, work continued in a manner similar to that used in laying out circular curves.

This, however, sometimes results in trouble for inexperienced men.

2nd: The *Polychord Spiral,* in which the degree of curve increases with each chord, in arithmetical progression.

The polychord spiral, with an infinite number of chords, is the track parabola.



Reduced to its simplest form, the polychord becomes what might be called a *One Chord Spiral.*

The latter is a terminal circular curve having a radius $2R_M$ (see dotted curve Fig. 1).

The values of p and R being fixed, all polychord spirals will fall between the one chord spiral and the track parabola, and the greater the number of chords, the nearer the approach to the track parabola.

For fixed values of p and R_M, each form of spiral has its own appropriate length, the one chord being the short-

est and the track parabola the longest, all the polychords falling in between; the greater the number of chords the longer the spiral.

In practice, the maximum lateral variation of a six chord from a parabola will not exceed 0.02 feet. The usual variation is negligible in this class of work. Hence the principal easement curves in use yield alignments which approach each other so closely that their riding qualities are the same.

The total length of track, between common points on the main tangent and main curve, is also the same, no matter what spiral be used, so that, after track is laid to a one chord, it may be thrown into a track parabola without altering the expansion.

The three principal classes of polychords are:

1st. With deflections constant, while chord length and number of chords vary (such as the Searles form).

2nd. With chord length constant, while deflections and number of chords vary.

3rd. Number of chords constant, while deflections and chord lengths vary.

Most of these spirals depend for their usefulness on specially prepared tables which must be consulted in the field and their efficiency for varying values of p and R_M increases with the number of tables.

Thus, Searles has provided 500 tabulated spirals from which to select the one coming nearest to given values of p and R_M.

The spiral used in the following discussion is of the 3rd type and has invariably six chords.

The *Six Chord Spiral* is chosen:

1st. On account of its extremely simple relation to

the one chord spiral or terminal arc of half the degree of the main curve (see Fig. 2).

2nd. On account of its close approximation to the track parabola, and all polychords commonly used.

It will first be considered as a curve to be offset from the one chord spiral.

The offsets are small, and may usually be estimated, in a manner analogous to the use of the self reading rod in levelling.

The instrument is to be kept on the one chord spiral, and all calculations, shifts, etc., are made by the ordinary rules and tables for circular curves.

Notes are kept and plats made precisely as for compound curves.

The one chord is sufficiently exact for right of way descriptions.

Since the one chord and the six chord have the same length between common points no equation of distance is introduced in passing from one to the other.

To aid the eye in offsetting in the field of view of the instrument, a 2½ inch wrought iron washer may be put on the transit rod. This will give a 0.1 ft. offset on each side of the centre rod, which is usually a sufficient help for setting stakes.

A more exact makeshift may be obtained as follows:

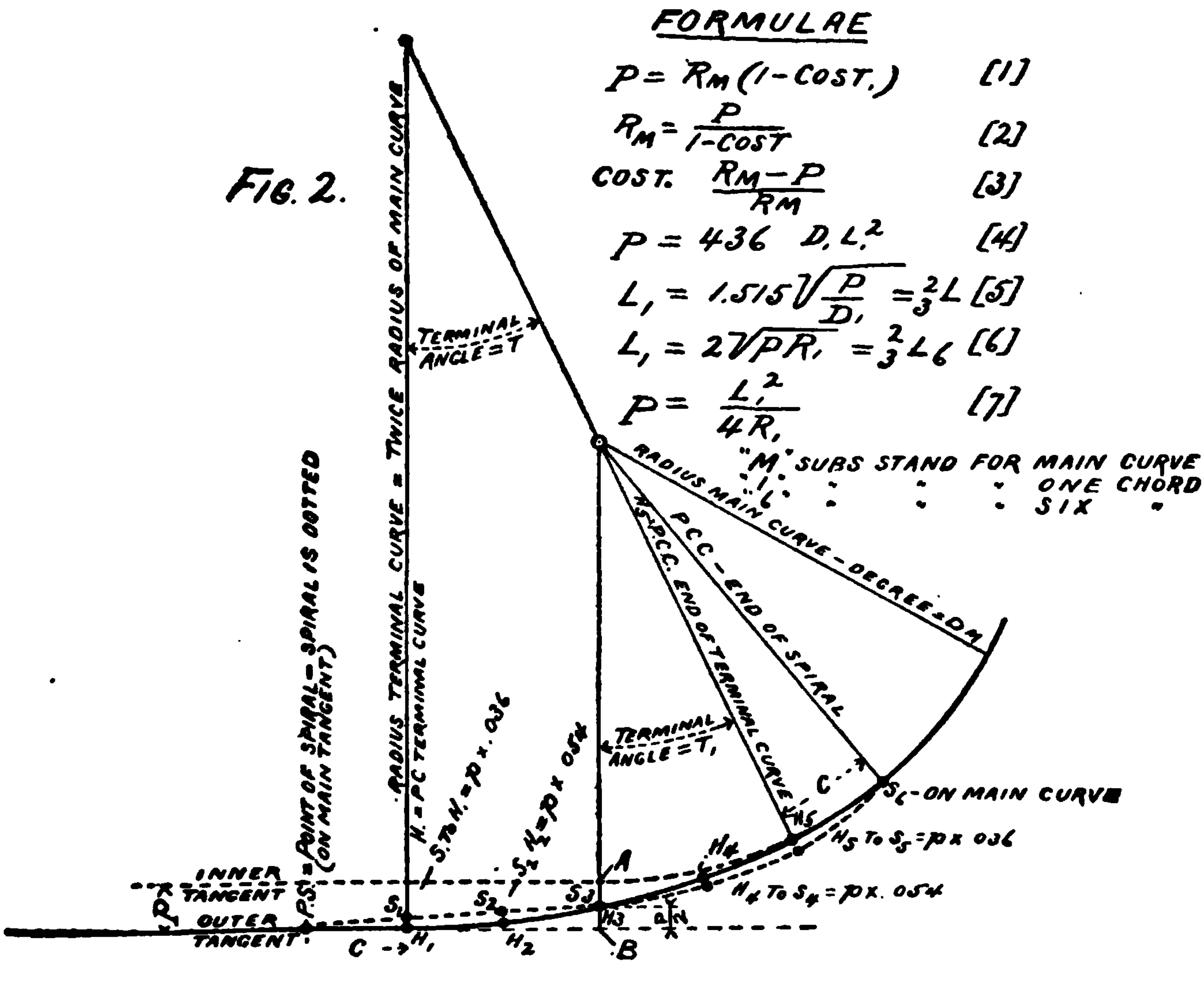
Take a two foot rule, cut off the two outside hinged legs, thus leaving the pivot joint with a six inch leg on each side. Screw one of these legs along a face of an ordinary wooden octagon rod.

The other leg will make a folding offset sight. This movable leg should have fastened to its face a strip of sheet iron say 6 in. long and 1 in. wide, in which **V** shaped notches are cut, deep ones for the full tenths from rod centre, and shallow for the half tenths.

When the vertical hair cuts the scale at the proper offset, set tack at point of rod.

In case the spiral is so long that a division into six parts gives too great a distance between track centres, it may be divided into twelve equal parts by taking every fifth point in Table 1.

FIG. 2.



THE SIX CHORD SPIRAL AND TERMINAL CURVE HAVING A RADIUS TWICE THAT OF MAIN CURVE

This will not constitute the regular twelve chord spiral, which would be longer and include a greater total angle than the six chord.

As a guide to section foremen in determining track elevation it is preferable to divide the spiral into some fixed number of equal parts regardless of the full stationing.

This spiral has six chords, each="C"=one-fourth length of terminal curve, hence spiral is $1\frac{1}{2}$ times length of terminal curve, and the quarter points, H_1, H_2, H_3, H_4 of the terminal curve, are abreast the one-sixth points, S_1, S_2, S_3, S_4 of the spiral. S_3 and H_3 coincide. $S_3A=S_3B$.

One-half the terminal curve is inside the spiral, the other half outside; and the offsets between them, at equal distances from H_3 or S_3, are equal. $H_1S_1=H_5S_5=.036P$ and $H_2S_2=H_4S_4=.054P$.

The offset $P=R_M\ (1-\cos T_1)=R_M \times$versed sine T_1, where R_M =radius of main curve, and T_1=the terminal

angle (a). $R_M=\frac{5730}{D_M}$

To locate the spiral, take the distance for gaining the required elevation$=L_6=6C$. [At the nearest multiple of six feet to avoid fractional chaining.]

Here C=chord and $L_6=6C$=length of spiral.

Then $\frac{2C\times D_M}{100}=T_1$ Where $\begin{cases} D_M\text{=Degree of main curve} \\ T_1\text{=Terminal angle in degrees} \\ C\text{=Length of chord in feet} \end{cases}$

Next calculate P from equation (a) above. Run in the terminal curve and offset to spiral. Locate P S and S_6 on outer tangent and main curve, one chord length from H_1 and H_5 respectively.

Note.—T_6, the total angle of six chord$=1\frac{1}{2}T_1$.

Note particularly that the length of six chord$=L_6$ is

1.5 times the length of the one chord=L_1, also as an aid to the memory that the offset .054=1.5 times .036.

In practice, taping p at 4 feet the offsets would be 4 times .054½=0.216 ft. and 4 times .036=0.144 ft.

Example.—Take a 14° curve having a spiral approach of six chords, each 25 ft. long or 150 ft. in all, to connect with a 7° approach, and calculate the offsets to spiral.

$R_M = 5730 \div 14 = 409.3$. $L_6 = 25 \times 6 = 150$.

T_1 (the terminal angle)=⅓ $L_6 \times D = 150 \times 14 \div 3 = 7°$, L_6 being expressed in one hundred foot units.

The main offset $p = R_M (1 - \cos T_1) = 409.3 \times .00745 =$ 3.05 feet.

The offsets $H_1S_1 = H_5S_5 = 3.05 \times .036 = 0.11$ ft.
$H_2S_2 = H_4S_4 = 3.05 \times .054 = 0.16$ ft.
$H_3S_3 =$ Zero.

The P. S. and S_6 are set as shown in Fig. 2.

The 7° approach from H_1 to H_5, or the one chord spiral will be four 25 ft. chords.

Whenever intermediate offsets are required, as in centering trestle bents, etc., the following table is used:

Table for intermediate offsets from main tangent and main curve with one chord approach, to the six chord spiral.

To be measured inward from the main tangent half of spiral and outward from the main curve half.

TABLE I.

Tenths of Chord length.	Coefficients which x p give offsets in feet.	Tenths of Chord length.	Differences for each hundredth of chord length.	Tenths of Chord length.	Coefficients which x p give offsets in feet.	Tenths of Chord length.	Differences for each hundredth of chord length.	Tenths of Chord length.	Coefficients which x p give offsets in feet.	Tenths of Chord length.	
P.S.	.000	S_6		S_1	.036	S_5		S_2	.054	S_4	
			.0000				.0006				.0004
1	.000	9		1	.042	9		1	.050	9	
			.0001				.0006				.0004
2	.001	8		2	.048	8		2	.046	8	
			.0002				.0004				.0005
3	.003	7		3	.052	7		3	.041	7	
			.0003				.0004				.0005
4	.006	6		4	.056	6		4	.036	6	
			.0003				.0002				.0005
5	.009	5		5	.058	5		5	.031	5	
			.0004				.0001				.0005
6	.013	4		6	.059	4		6	.026	4	
			.0005				.0000				.0006
7	.018	3		7	.059	3		7	.020	3	
			.0005				.0000				.0006
8	.023	2		8	.059	2		8	.014	2	
			.0006				.0002				.0007
9	.029	1		9	.057	1		9	.007	1	
			.0007				.0003				.0007

Example.—In the preceding example let the P. S. be

at station 7+07, chords 25 feet, required the offset at the even station 8. The curve may be tabulated thus:

$$\left.\begin{array}{l} P.S.=7+07 \\ S_1=7+32 \\ S_2=7+57 \\ S_3=7+82 \\ S_4=8+07 \end{array}\right\} \begin{array}{l} \text{Hence } 8=S_3+18/25=S_3+0.72 \\ \text{toward } S_4\text{, which by interpolation in table I} \\ =.042 \text{ and,} \\ .042\times p \text{ or } 3.05=.128 \text{ ft.} \end{array}$$

If the numbering ran in the opposite direction, the offset at 6+40 being required then,

$$\left.\begin{array}{l} P.S.=7+07 \\ S_1=6+82 \\ S_2=6+57 \\ S_3=6+32 \end{array}\right\} \begin{array}{l} \text{Here } 6+40=S_3+8/25=S_3+0.32 \\ \text{toward } S_2 \text{ which by table I} \\ =.0212\times 3.05=.074 \text{ ft.} \end{array}$$

In case a simple curve has been run in connecting the main tangents, as in Fig. 1, no provision being made for spiraling, the circular curve is moved inward, without altering the original radius, along the line B C, for the distance E F$=p\div\cos \frac{1}{2}$ I where p is the principal offset, and I the total angle turned between tangents, E F being parallel to B C.

Also E G$=p \tan \frac{1}{2}$ I.

The distance G H back to the P C is one-half the long chord of the one chord spiral approach.

Hence G H$=R_1 \sin \frac{1}{2} T_1$

And E H $=R_1 \sin \frac{1}{2} T_1+p \tan \frac{1}{2}$ I.

In order to avoid small equations and to fit the ground from the start, the one chord spiral should be run in on the first located line that is likely to become final.

COMPOUND CURVES.

Whenever the degrees of curvature of the two members of a compound curve differ materially, they should be connected by a spiral.

This spiral should be run in on the original location, to save the trouble of subsequent shifts, equations, etc.

The general method before described, of offsets from a one chord to a six chord spiral, may be applied equally well in this case.

The one chord connection averages the degrees of the adjacent main curves.

Thus a 4° compounding into an 8° will have a one chord connection of $\frac{1}{2}(8+4)=6°$.

To make room for this intermediate 6°, a sufficient offset between the two main curves must be allowed, and the sharper curve must lie inside the lighter one.

The length of the one chord spiral, the principal offset or gap p, and the intermediate offsets are determined as follows:

Take the 4°, 6° and 8° combination and assume that the whole curvature is uniformly "bent" outward until the 4° becomes a tangent, the 6° a 2°, and the 8° a 4°.

We then have the conditions of a 4° curve from tangent, and the necessary calculations are made, as before shown, to fit these conditions.

P. S. to $S_1 = S_5$ to $S_6 = \frac{1}{4} S_1S_5 = \frac{1}{4} H_1H_5$. $AS_3 = AH_3 = BS_3 = BH_3$. $H_1H_3 = H_3H_5$.

Note.—All "H" points are on one chord spiral.
"S" " " " six " "

Example.—(See Searles R. R. spiral, page 63, Art. 55.)

Given a compound curve in which $d'=6°$ and $d''=10°\ 40'$ to replace the P. C. C. by a spiral having six chords of 25 ft. each (P. S. to S_6, Fig. 3).

First determine the data for the one chord H_1H_5, Fig. 3.

Its degree $d_1=\frac{1}{2}\ (10°\ 40'+6°)=8°\ 20'$.

Its length $l_1=4\times 25=100$ ft.

Its total angle $t_1=8\frac{1}{3}\times 100=8°\ 20'$, of which $d'\times\frac{1}{2}\ l_1=6°\times.50=3°$ is deducted from the 6° & $d''\times\frac{1}{2}\ l_1=10°\ 40'\times.50=5°\ 20'$ is deducted from the 10° 40'.

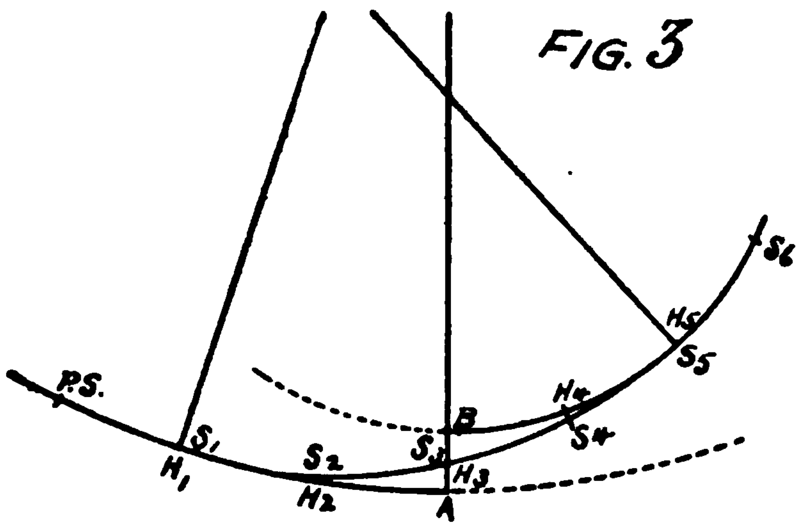


FIG. 3

P.S. TO S_1 = S_5 TO S_6 = $\frac{1}{4}\ S_1S_5$ = $\frac{1}{4}\ H_1H_5$ $AS_3=AH_3=BS_3=BH_3$ $H_1H_3=H_3H_5$

NOTE – ALL "H" POINTS ARE ON ONE CHORD SPIRAL
" "S" " " " SIX " "

The total angle of the six chord spiral will be $8°\ 20'\times 1.5=12°\ 30'$ of this.

$d'\times\frac{3}{4}\ l_1=6°=.75=4°\ 30'$ is deducted from the 6°.

And $d''\times\frac{3}{4}\ l_1=10°\ 40'\times.75=8°\ 00'$ is deducted from the 10° 40'.

Note, that in this case the choice of a six chord spiral by Searles is accidental. The above reasoning would not obtain had any other chord number been chosen.

Now assuming, as before, that the 6° curve (the lightest of the three) be bent straight, the $8^\circ\ 20'$ curve becomes a $2^\circ\ 20'$ and the $10^\circ\ 40'$ becomes a $4^\circ\ 40'$.

Hence the conditions are a $2^\circ\ 20'$ one chord approach from tangent to a $4^\circ\ 40'$ main curve.

The terminal angle for 100 feet of $2^\circ\ 20'$ curve$=2^\circ\ 20'$ and $p_1 = .436 \times 2.33 \times 1 = 1.02$ (see For. 4 Fig. 2) or $p_1 = 1228 \times .00083 = 1.02$ (see For. 1 Fig. 2), which is the value given by Searles, page 65.

Then with the instrument at H_1 or H_5 (each being two chord lengths or 50 ft. from the middle point S_3 or H_3) run in the $8^\circ\ 20'$ one chord spiral and offset.

$H_1S_1 = H_5S_5 = 1.02 \times .036 = .037$ ft.

$H_2S_2 = H_4S_4 = 1.02 \times .054 = .055$ ft.

Intermediate offsets are interpolated from Table I, as before shown.

Since in this particular case the maximum difference between the one chord and six chord is but ¾ inch, the six chord might well be omitted until it comes to the final adjustment of the track.

Note the direction of the offsets, outward from the one chord line on sharper curve half, and inward on lighter curve half.

Similarly to the above the length of the one chord when p_1 is given may be determined from formulæ 3, 5 and 6, Fig. 2, taking $4^\circ\ 40'$ as the main curve.

To shift the two members of a compound curve so that suitable spirals may be inserted.

Let L E F, Fig. 4, be a compound curve with B and C as centres (b and c being the total angles), which has been run in without provision for spirals.

Required to insert spirals without changing the degree of either branch of the original compound.

The required offsets p and P, Fig. 4, are to be taken for spirals having a length suitable for the speed and elevation proposed.

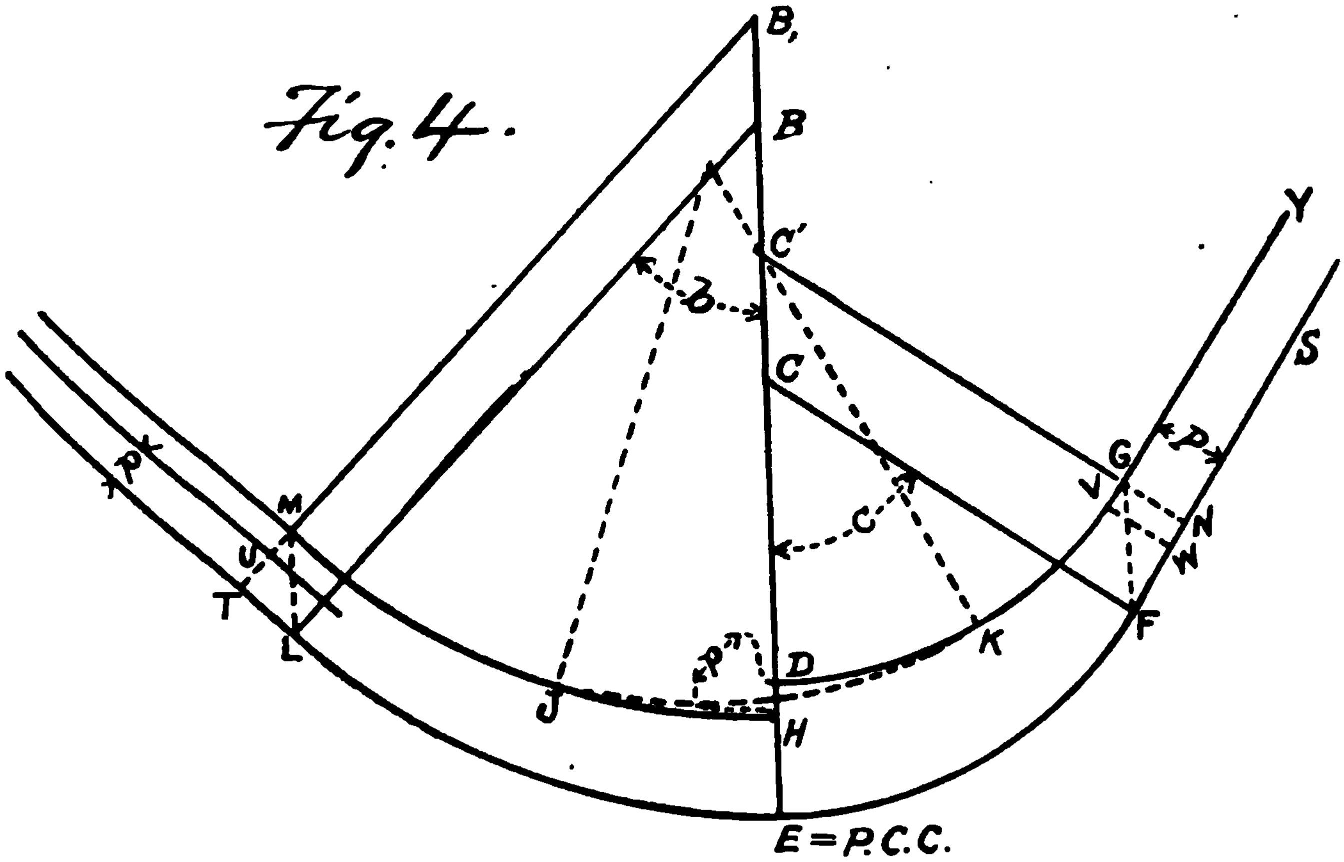
Assume that the curve E F is slid inward, along the radial line E B common to both curves, until F falls on G, E on D and C on C′.

Then F G parallel & equal to E d$=\dfrac{P}{\cos c}$

Where P= G N and ang. F G N=c

Also F N=P tan c.

Fig. 4.



Next determine the proper offset p, for a one chord J K uniting the two members of the compound (see Fig. 3 and following).

Then E H=E D—$p_1=\dfrac{P}{\cos c}-p_1$.

Assume that the curve E L is moved inward until E

falls on H and L on M. E H being equal and parallel to M L

Since angle T M L= b M T= M L cos b

$$\text{Hence } M\ T = \left(\frac{P}{\cos\ c} - p_1\right) \cos b$$

If the curve had been thus run in, the P. T. at M would be a distance, M U too far out to fit the spiral selected, whose principal offset is p.

To make this fit, the provisional P C at G must be pushed ahead, along Y G produced, for a distance.

$$G\,V = W\,N = \frac{\left(\dfrac{P}{\cos\ c} - p_1\right) \cos\ b - p}{\sin\ (b + c)}$$

If b+c exceeds 90°, its sine will be sin (180—(b+c))

F W= P tan c—W N

From W add the distance back to S making W $S = R_1$ sin ½ T_1 where $R_1 = 2$ C F (see also equation 7, Fig. 2).

The whole curve, with one chord spirals may now be run in, remembering to deduct from the total angle c, the terminal angle of its spiral to tangent, plus the angle K C′ D of the one chord K J.

Similarly the total angle b is reduced by its terminal spiral angle plus the angle J B′ H.

Angle K C′ D=½ J K×degree of curve E F

" J B′ H=½ J K× " " " E L

In the case of a long compound, minor differences in running may be adjusted by shifting J, the end of the one chord (see Shunk, page 101, and Searles, page 113).

This should be done by first running out the full curve J M, and before attempting to put in the final spiral.

In some cases it will be necessary to shift the original P. C. C. before room can be made for end spirals.

In making any or all of these shifts, the nature of the ground should be kept in mind, in order to gain the advantages of a general revision of the line. For this purpose, a large scale special plate is often of use.

FIG. 5.

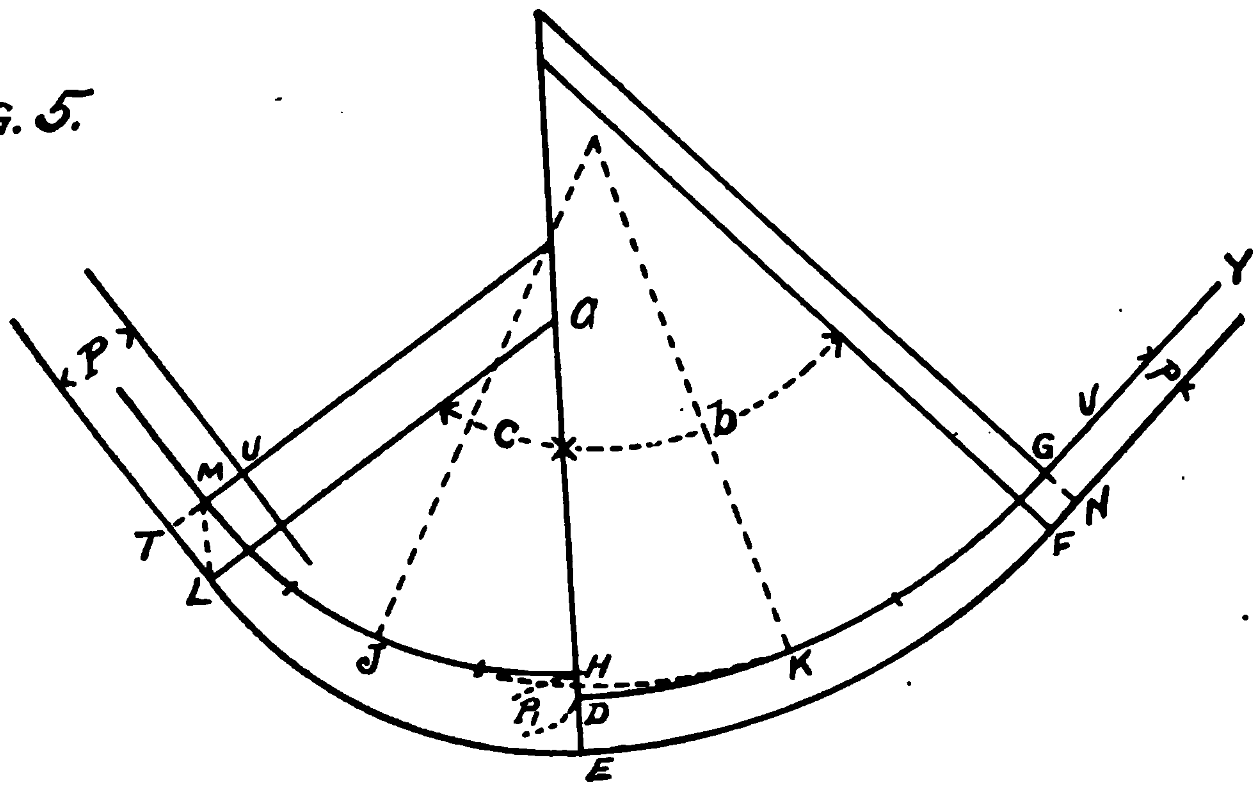


Fig. 5 indicates the process, when the curve is to be run in from the lighter end.

Here ang. F G N= b

Then F G parallel and equal ∽ $E\ D = \frac{p}{\cos b}$

$F\ N = p \tan b \quad D\ H = p_1$

$$E\ H = E\ D + p_1 = \frac{p}{\cos b} + p_1 = L\ M = \frac{p}{\cos b} + p_1$$

ang. T M L=c

Then $T\ M = L\ M \times \cos c = \left(\frac{p}{\cos b} + p_1\right)$

$$\cos c = \left(\frac{p}{\cos b} + p_1\right) \cos C.$$

$T\ U = P$ the required offset $= T\ M + M\ U$
Hence the shift required is

$$P - T\ M = P - \left(\frac{p}{\cos b} + p_1\right) \cos c$$

and the necessary full back

$$G\ V = \frac{P - \left(\frac{p}{\cos b} + p_1\right) \cos c}{\sin (b + c)}$$

The rest of the process is the same as in the preceding case after G V has been obtained.

THE LENGTH OF SPIRALS.

There is no definite rule for determining the length of spirals. This depends on both speed and elevation.

The rate on which the given elevation is to be obtained is also important.

Some rules for spiral length are based on a uniform rate of elevation grade, such as 1 in 300, 1 in 400, etc.

The rational rule for varying speeds is that the same amount of super-elevation should be attained in the same time.

This may be called the *"time approach."*

It follows that curves of the same degree, operated

under different speed conditions, should have spiral lengths proportional to the cubes of the speeds used.

The following tables indicate the relations between spirals, and the data used to determine their lengths.

TABLE II.

Degree main curve.	Degree one chord spiral.	Maximum safe speed.	Elevation.	Offset p.	Length of one chord spiral.	Length of six chord spiral.	Rate of elevation grade—speed $\times 6 \div E\ L = \frac{6}{.5} = 12$
1	0-30	100.	.5	3.5	400.0	600.0	1 in 1200
2	1	70.7	.5	3.5	282.8	424.2	1 in 848
3	1-30	57.7	.5	3.5	230.8	346.2	1 in 692
4	2	50.0	.5	3.5	200.0	300.0	1 in 600
5	2-30	44.7	.5	3.5	178.8	268.2	1 in 536
6	3	40.8	.5	3.5	163.2	244.8	1 in 490
7	3-30	37.7	.5	3.5	151.0	226.5	1 in 452
8	4	35.4	.5	3.5	141.6	212.4	1 in 425
9	4-30	33.3	.5	3.5	133.2	199.8	1 in 400
10	5	31.6	.5	3.5	126.4	189.6	1 in 379

In the above table, the maximum safe speeds are, for convenience, taken as the reciprocals of the square roots of the degrees of main curve×100; also

Length of one chord spiral=max. speed×4

" " six " " = " " ×6

Note from Table II that for curves operated under the same conditions of safe speed and with time approaches, the offsets p and the elevation are constant.

The following convenient rules for lengths of spirals are also indicated in the table:

Rule I.—Length of six chord equals speed in miles per hour multiplied by elevation in inches.

Here maximum p=3.5 feet.

Rule II.—If somewhat longer spirals be desired, then

Length of one chord spiral equals speed in miles per hour multiplied by elevation in tenths of feet.

Here maximum p=5.45 feet.

Other rules, yielding longer or shorter spirals as desired, may be formed on the same plan.

The following table of elevations explains itself. The elevations are in decimals of a foot.

TABLE III.

Speed in Miles Per Hour.

Degree of Main Curve.	31.6	33.3	35.4	37.7	40.8	44.7	50.0	57.7	70.7	100.0
1	.05	.06	.06	.07	.08	.10	.13	.17	25	.50
2	.10	.11	.13	.14	.17	.20	.25	.34	.50	
3	.15	.17	.19	.21	.25	.30	.38	.50		
4	.20	.22	.25	.29	.33	.40	.50			
5	.25	.28	.31	.36	.42	.50				
6	.30	.33	.38	.43	.50					
7	.35	.39	.44	.50						
8	.40	.44	.50							
9	.45	.50								
10	.50									

Now finding a 5° curve which is elevated .36 ft. and giving satisfaction as to rail wear, comfort, etc., a glance

at Table III shows that it belongs to the 7° maximum series, having a speed of 37.7 miles per hour.

The length of spiral required would be adopting Rule I under Table II $.36 \times 12 = 4.32$ ins. & $4.32 \times 37.7 = 162.9$ ft. for the length of a six chord spiral, and $162.9 \times 2/3 = 108.6$ ft., the corresponding one chord spiral.

If Rule II be adopted, then—

$10 \times .36 \times 37.7 = 135.72 =$ length of one chord & $135.72 \times 1.5 = 203.58 =$ length of six chord.

It may sometimes be advisable to use longer easements on certain curves, so that, if the speed limit be increased, the elevation only need be changed, the alignment remaining fixed.

For construction purposes it is necessary to divide the line into speed sections of suitable length, treating each section by itself.

A speed section may sometimes be as small as a single sharp curve, or even the sharp member of a compound curve.

The Length of Spirals Joining Compound Curves.

This should obviously be sufficient to gain the proper difference of elevation between the two curves, or what is the same thing, the length for a spiral from tangent to a curve whose degree is the difference between the two members of the compound.

For example:

A 5° curve compounds with a 3° required the length of one chord connection using Rule II.

$5°-3°=2°$. Then assuming speed at 40.8 miles, column 6, Table III, gives elevation for a $2°=.17$ ft.

Then $1.7 \times 40.8 = 69.4$ = length of one chord spiral. Length of six chord $= 69.4 \times 1.5 = 104.1$ ft.

To Run in the Six Chord Spiral by Deflections.

The degrees of curvature of the six arcs of the spiral are, D/7 2D/7 3D/7 4D/7 5D/7 and 6D/7, 7D/7=D being the degree of main curve (see Fig. 2).

The angle of crossing of the six chord and one chord

$$\text{at } S_3 \text{ or } H = \frac{D \times C}{700},$$

when both D and the crossing angle are expressed in degrees and decimals and C equals the length of the single chords in ft.

$$\text{The total angle of the six chord} = \frac{D \times L}{200}$$

The following table gives the deflections with transit located at P. S. S_3 and S_6 with zero on tangent at each transit point respectively.

The coefficients given are to be multiplied into $C \times D$ (with D in degrees and C in feet). The product will be the deflections from tangent at instrument in minutes and decimals.

Logarithms of coefficients if used should be added to Log. $(C \times D)$.

TABLE IV.

Deflection Table for Six Chord Spiral—Zero on Tangent.

	Inst. on P.S.		Inst. on S_6		Inst. on S_3		
Point	Coeff.	Log of Co	Coeff.	Log of Co	Coeff.	Log of Co	Point
P. S.	Zero		1.1500	0.06070	0.3143	9.49733	P. S.
S_1	0.0429	8.63202	1.0286	0.01223	0.2357	9.37239	S_1
S_2	0.1072	9.02996	0.8786	9.94378	0.1286	9.10909	S_2
S_3	0.2000	9.30103	0.7000	9.84510	Zero		S_3
S_4	0.3214	9.50708	0.4929	9.69272	0.1714	9.23408	S_4
S_5	0.4714	9.67342	0.2572	9.41018	0.3643	9.56144	S_5
S_6	0.6500	9.81291	Zero		0.5857	9.76769	S_6

Example.—Take a 14° curve having a spiral approach of six chords each 25 ft. long or 150 ft. in all, to calculate the deflections.

Here $C \times D = 25 \times 14 = 350$ log. $= 2.54407$

Then from Table IV Inst. on P. S.

S_1	S_2	S_3	S_4	S_5	S_6
8.63202	9.02996	9.30103	9.50708	9.67342	9.81291
2.54407	2.54407	2.54407	2.54407	2.54407	2.54407
1.17609	1.57403	1.84510	2.05115	2.21749	2.35698
15′	37.5′	70′	112.5′	165′	227.5′
0° 15′	0° 37½′	1° 10′	1° 52½′	2° 45′	3° 47½′

With Inst. at S_6 to turn tangent to the six chord and main curve at S_6.

Sight on P. S. with vernier set at (see Table IV) $1.15 \times C \times D = 1.15 \times 350 = 402\frac{1}{2}' = 6° \ 42\frac{1}{2}'$, and then

turn vernier to zero, or, sighting on S_3, $0.7 \times 350 = 245'$ $= 4° \ 05'$, which is to be turned off at S_6 to obtain tangent.

These computations may be made by logarithms, as before.

For Inst. at S the crossing angle between the spiral and the 7° curve (one chord spiral) will be $C \times D \div 700 = 350 \div 700 = 0.5 = 0° \ 30'$ and from this, one may pass from one curve to the other.

The total angle of the six chord is $D \times L \div 200 = 14 \times 150 \div 200 = 10° \ 30'$.

To calculate the deflections for a six chord spiral joining two members of a compound curve.

See example under Fig. 3.

First calculate the deflections by Table IV for 150 ft. of six chord spiral joining a tangent with a $10° \ 40' - 6° = 4° \ 40'$ main curve.

Then to each deflection thus found add that of a 6° curve for the length of sight taken.

Thus from P. S. to S_1 add 45'.
" S_3 " S_6 " 2° 15'

If so desired, necessary tabulations may be prepared in advance, giving once for all the deflections required for the general run of curves in use, precisely as is customary with all table spirals.

If desired coefficients for Instrument on S_1 S_2 S_4 and S_5 may be computed and arranged as in Table IV, but the method of offsets from the one chord spiral is preferable.

TRACK PARABOLA.

The following (Table V) may be used in offsetting from the one chord spiral to the track parabola.

Tables I and V are on the same base and may be similarly used.

It will be noticed that the differences between the corresponding offsets in Tables I and V are, for any usual value of p, too small to be noteworthy.

In actual service, the parabola has no advantage whatever over the polychord spiral, and a choice between them should be governed by their relative adaptability to field and office use.

The offsets in Table V are to be measured inward from the main tangent half of spiral, and outward from the main curve half.

Note that the offsets at P. S. are insignificant.

For $p=10$ ft. they are 0.01 ft.

TABLE V.

Table of intermediate offsets from main tangent and main curve with one chord approach to track parabola.

Tenths of Chord length.	Coefficients which x p give offsets in feet.	Tenths of Chord length.	Differences for each hundredth of chord length.	Tenths of Chord length.	Coefficients which x p give offsets in feet.	Tenths of Chord length.	Differences for each hundredth of chord length.	Tenths of Chord length.	Coefficients which x p give offsets in feet.	Tenths of Chord length.	Differences for each hundredth of chord length.
P.S.	.001	S_6		S_1	.038	S_5		S_2	.055	S_4	
			.0001				.0007				.0003
1	.002	9		1	.045	9		1	.052	9	
			.0001				.0006				.0004
2	.003	8		2	.051	8		2	.048	8	
			.0002				.0004				.0005
3	.005	7		3	.055	7		3	.043	7	
			.0003				.0003				.0005
4	.008	6		4	.058	6		4	.038	6	
			.0003				.0002				.0006
5	.011	5		5	.060	5		5	.032	5	
			.0004				.0001				.0006
6	.015	4		6	.061	4		6	.026	4	
			.0004				.0000				.0006
7	.019	3		7	.061	3		7	.020	3	
			.0005				.0001				.0006
8	.024	2		8	.060	2		8	.014	2	
			.0007				.0002				.0007
9	.031	1		9	.058	1		9	.007	1	
			.0007				.0003				.0007
S_1	.038	S_5		S_2	.055	S_4		S_3	.000	S_3	

The relative lengths and total angles of spirals for constant values of p and R_M (see Fig. 1).

Let L_1=length or total angle of one chord spiral.

L_6= " " " " " six " "

Lp= " " " " " track parabola.

Then $L_6=1.5L_1$ $L_1=\frac{2}{3}L_6$ $L_1=.577Lp$

$Lp=1.733L_1$ $Lp=1.155L_6$ $L_6=.866Lp$

Example: Given $R=1432.5=4°$ curve
$P=4.65$

The total angle of a one chord, will be (For. 3, Fig. 2) $4° \ 37'=4.617°$.

The total angle of a six chord
$4.617° \times 1.5=6.926°=6° \ 55\frac{1}{2}'$.

The total angle of track parabola
$4.617° \times 1.733=8° \ 00'$.

Length one chord $=4.617 \div 2°=230.85$ ft.
" six chord $=230.85 \times 1.5=346.28$ ft.
" parabola $=230.85 \times 1.733=400.00$ ft.

These lengths are bisected at S_3, which is the middle point of all spirals.

In the foregoing example, $400-230.85=169.15$ ft. is the difference, $Lp-L_1=.733 \ L_1$.

Hence $169.15 \div 2=84.58$ ft., is the distance to be laid off along main tangent or main curve, from the beginning or ending of the one chord, in order to obtain the beginning or ending of the track parabola. This may be used in connection with Table V, when it is desired to lay off the track parabola.

The total angles of the spirals will be divided at the middle point S_3 as follows:

One	chord	4.617°	$\frac{1}{2}=2.31°$	on tangent half.
"	"	4.617°	$\frac{1}{2}=2.31°$	on main curve half.
Six	"	6.926°	$2/7=1.98°$	on tangent half.
"	"	6.926°	$5/7=4.95°$	on main curve half.
Track	parabola	8°	$\frac{1}{4}=2°$	on tangent half.
"	"	8°	$\frac{3}{4}=6°$	on main curve half.

In all spiral running it is important to keep a watch

on the total angles of the various parts, so that the grand total, from tangent to tangent, will check with the intersection angle of the whole curve.

NOTE: Illustrations of the various instruments used in making the surveys will be found in the appendixes at end of this volume.

SECTION II.

MAINTENANCE OF WAY.

The Roadbed.

The railroad completed and having been, so to speak, delivered to the operating department, we may suppose it to be performing its functions, and that with passenger and freight trains now being hauled daily over its tracks, the next thing to care for is the maintenance of the roadbed, the surfacing and lining of the track, renewals of ties, rails, frogs, switches, etc., and the improvements which always follow after construction.

The increased weight of the rolling stock, particularly of locomotives, and also, the heavier trains hauled, is constantly making more and more difficult the problem of maintenance of roadbed, track and bridges.

We will first consider the maintenance of the roadbed. The greatest difficulty met is that of drainage. Mr. L. R. Zollinger, Engineer of Maintenance of Way, Pennsylvania Railroad, an eminent authority upon the subject of roadbed maintenance, says:

"Water is the greatest enemy to the roadbed, so that good drainage becomes a matter of vital importance. Without ditches of sufficient width and depth the ballast will soon become filled with dirt and other impervious material, which act as a dam to hold the water under the track. In winter the freezing of this water causes 'heaving track,' which destroys the true surface of the rail,

while at other times it causes 'pumping,' especially at the joints, which likewise result in uneven surface (Fig. 1). It is therefore necessary at all times to keep the ditches open their full width and depth. If, during construction, the cuts were not made sufficiently wide and deep to provide a proper ditch, one of the first requirements after the road is turned over to the roadmaster is to widen them

Fig. 1. Low Joints Caused by "Pumping."

out. The shoulder of the ditch next to the track should be low enough to insure a fall from the bottom of the ballast at the center of the track; the ballast border should be wide enough to hold the ends of the ties in line.

"The standard ditch on the Pennsylvania Railroad for a four-track road calls for a distance of 10 feet 6 inches from the rail and 3 feet below the base of it to its outer edge. Fig. 2 shows a ditch built to standard specifica-

tions, the standard section in the foreground and beyond it a ditch that will not afford the proper drainage. The shadow of the telegraph pole falling across the ditch at right angles shows clearly the section, which can be compared favorably with the Pennsylvania Railroad standard plan (Fig. 3).

Fig. 2. Ditch Built to Standard Specifications

"The material cleaned from ditches in a side hill cut is usually carried across the track and wasted. In a short through cut it may be carried out to the ends with wheelbarrows; but in a long cut a work train is used, the material is loaded on low cars by shovels, or by mechanical means. It is unloaded on embankments that have not sufficient width or at other places where filling is needed; this is done by hand or by plow unloader.

"The maintenance of the ditch becomes an expensive operation, and any expenditure to reduce the washing or erosion of the slope is well made. Where the material is of clay, or a mixture with that material, slides are usually aggravating. By placing porous tiles under the surface, running down the slope, at an angle of 45 degrees, the sub-surface water can be conducted away without damage to the bank. To cover the slope with sod or other vegetation will protect it from erosion, and a berme ditch on top will catch the surface water from above. A very satisfactory way of maintaining the surface of a wet cut, where the expenses will warrant, is to hold the slope with a *low* masonry toe wall, with weep holes at the bottom, which allow the water to seep out. If the slope is

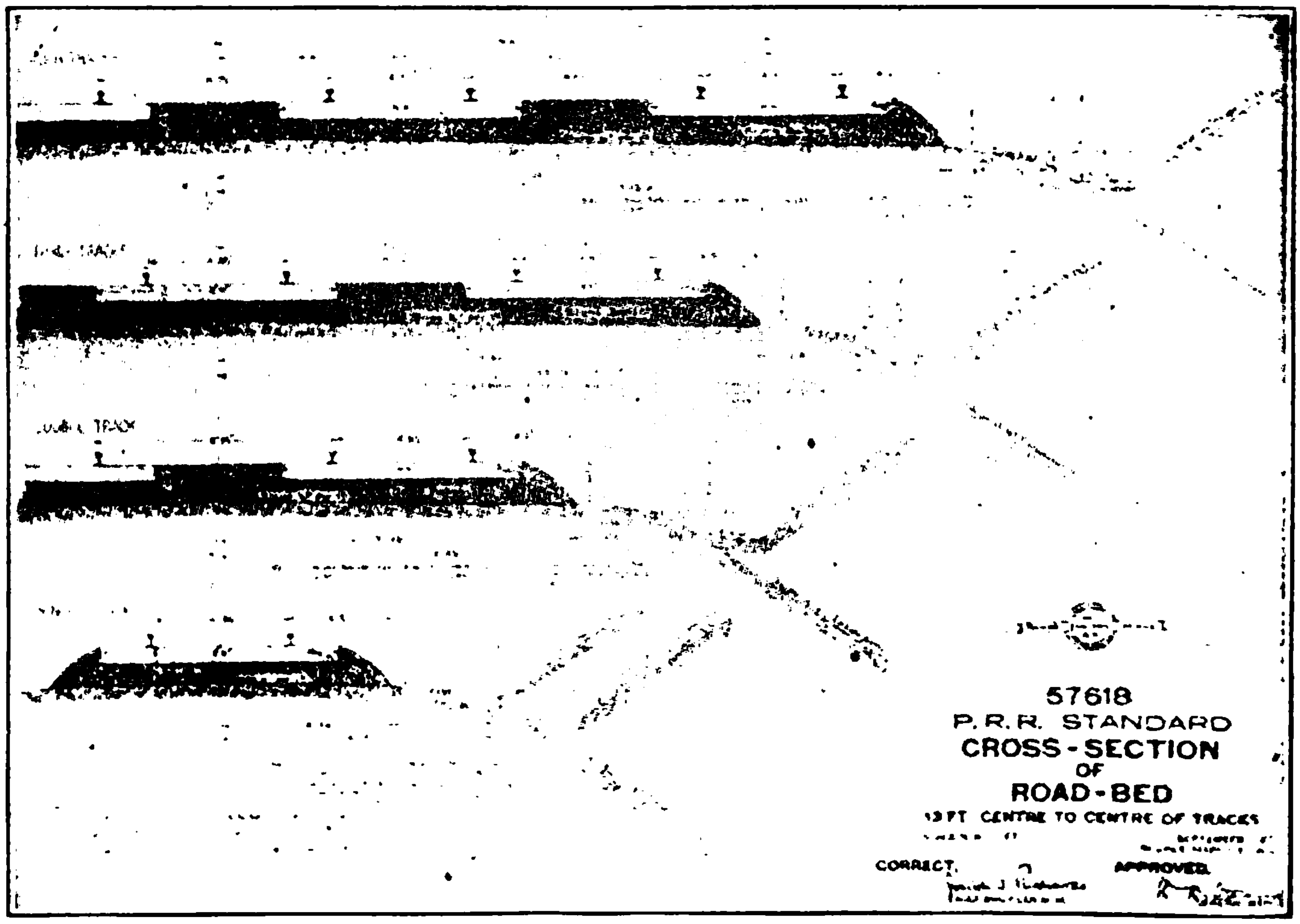


Fig. 3. P. R. R. Standard Ditch and Roadbed.

then sodded, there need be little fear of any further trouble (Fig. 4).

"In towns or at points where the work will be of lasting character, the ditches can be paved with flat stones, cobbles or concrete; such ditches are easily maintained and flush themselves during heavy rains. Fig. 5 shows a section of concrete ditch as constructed along the Pennsylvania Railroad near Ardmore.

Fig. 4. Toe Wall Holding Embankment.

"Before a bank is considered in fit shape for sod, it should be carefully sloped. The angle of the slope should be made to suit the material in it—solid rock, of course, will stand almost vertical, loose material will stand at different angles. The common slope for dirt is one and one-half to one, meaning a base of one and one-half times

the vertical height. Quicksand, and unstable material of that character, may require a slope of two or even three to one. Loose rock will usually stand at a one to one slope. Experience is necessary to determine the necessary slope, and even the best judgment will err. When such a mistake is made, there may be several ways to rectify it; either to remove the material from the ditch

Fig. 5. Concrete Ditch.

as fast as it slides in until it finds its natural slope or angle of repose, or to resort to tiles and sod, or, lastly, to build a toe wall such as heretofore described. Such a wall may be built of stone, or a crib made of old crossties, or other timbers and filled with stone may be substituted to save expense. Such construction will last for many years. If there are springs, or if the material

indicates that it will slide when the frost comes out of the ground, porous tile drains should be laid a foot or more under the surface at an angle of 45 degrees, close enough together to insure drying up the surface. A cheaper method, and one which is satisfactory, provided the cut is not too wet, is as follows:

"Heavy wooden stakes, two or more feet long, are driven down at right angles to the surface, eight feet apart in the row and the rows every six feet from the bottom to the top of bank. The stakes in the row are then made to support hemlock or other cheap plank, which are placed under the surface. The surface is again sloped and, if convenient, a thin layer of good soil is added to insure the growth of the sod, which is lastly laid in the usual manner. Where sod is not to be had, grass and oat seed may be sown and raked in; this in a favorable season will be successful, a dashing rain, however, would wash it away and the labor would be lost.

"In some sections near large cities where street sweepings can be had, such material is used to cover the banks, grass and oat seed being added. On account of the fertilizer in the sweepings a sod is soon formed, the oats grow very quickly, throwing out a large number of roots, which at once protect the bank from washing, the stalk serving to protect the young grass from the heat of the sun."

Continuing, he says: "Retaining walls of considerable size should be built by masons. Small ones can be constructed by track men. Care should be taken to dig out the foundation below the frost line, and to a firm bed; the stone must be laid on their flat sides, the face of the wall should slope with a pronounced batter, usually not less than two inches horizontal to one foot vertical.

Weep holes must be left, or pipes inserted for drainage. If the bank be excessively wet, a French drain or a line terra-cotta pipe should be laid along the back edge of wall connected to the weep holes.

"There is another method of holding the toe of a bank. Stones somewhat flat in shape are laid on their edges following the slope of the bank. These prevent the surface earth from sliding. If used on the side of

Fig. 6 Terra-Cotta Drain Tiles.

a bank next to a stream it is a very good method of protecting the embankment from scouring by the water, especially on curved embankments where the force of the current is directed against the slope. This method is known as 'rip-rap,' but it must be regarded as a surface protection only; it is not a retaining wall.

"Having gotten the ditches in proper form, the banks sloped and protected, it becomes necessary to provide

means of conveying the water that falls on the track and roadway proper to ditches.

"The roadbed is constructed high in the center, the surface sloping both directions in order to convey the water as it percolates through the ballast to the ditches on either side. We find, first of all, in wet cuts, that

Fig. 7 Drain Tiles Venting into Side Ditch.

water rises under the roadbed, keeping it continually saturated, and the ballast by the weight of traffic is forced into this plastic material, and that it is quite impossible to keep the track in surface. This situation is met by digging transverse trenches sufficiently close together and below the surface of the roadbed and laying in these unglazed terra-cotta pipe below the frost line. These pipes are laid on inch boards, six inches wide, to

keep them in line and covered with broken stone, cinder or other permeable material. Fig. 6 shows the kind of tiles used, and Fig. 7 shows ends of pipe at ditch line after they have been laid.

"If the traffic is exceptionally heavy, iron pipes should be substituted for tile in the transverse drains, and the water led to these by longitudinal drains of porous tiles or iron pipes laid in the inter-track space.

Fig 8 Forking and Cleaning Stone Ballast.

"The ballast itself, even when carefully made, will, in time, become filled with dirt, ashes and other material, to such an extent that it will not permit the water to pass freely, or if the stone is soft enough to crush under heavy traffic, it will grind into powder and with water form a cement which is destructive to the drainage.

When such conditions obtain, it is necessary to dig up the ballast and remove all the dirt and fine particles with a tool known as a ballast fork. The dirt is carried out by hand, thrown over the banks, or piled up in the ditch to be removed by the work train; or if the roadbed has been soft or the ballast has been crushed, it may be necessary to restore the track to its original surface by elevating it and tamping the ballast under the tie in the new position. This is known as 'raising' track and should only be resorted to in order to restore the grade and should not be done as a substitute for cleaning ballast, as it leaves all the dirt below the tie, where it soon compacts and the drainage is again interfered with.

"Fig. 8 shows the method of cleaning ballast with a fork. After ballast is cleaned, or the track raised, it usually requires new ballast to fill up the inter-tie spaces. This is received in cars of the hopper type and unloaded on the tracks while the train is in motion, the material being leveled by the simple device of a cross-tie across the rails. See Fig. 9.

"Fig. 10 shows a finished and well maintained railroad. The slopes are sodded, the ditches in good condition, the track well filled with clean ballast."

Regarding ballast, he says: "The stone to be used on any particular portion of the road is generally determined by the local rock. The P. R. R. is so extensive that all kinds of stone are used, according to location. On the New York, the Maryland and Schuylkill divisions, and the West Jersey & Sea Shore Railroad, trap rock is used; on the P. R. R., N. C. Ry., P. & E. Division, and parts of the B. & A. V. Division, limestone is used. At various points, but not in large quantity, sandstone is used.

"Trap rock is the hardest and most durable, having a crushing strength of 18,000 pounds per square inch; some of the limestones are very soft, breaking under a crushing force as low as 3,000 pounds. We find on the P. R. R. that the heavy equipment and the numerous trains on the main line are crushing the limestone ballast, and it has been determined that trap rock or a stone of equal hardness or toughness will have to be substituted at an increased cost and with a longer haul.

Fig. 9 Distributing Stone Ballast—Leveling with a Cross-tie.

"The standard size of ballast on the P. R. R. and most other railroads is that of a stone that will pass through a 2½" ring, all small particles being removed by a screen of one inch mesh. It is probable that the specifications for ballast of trap rock will be changed to stone passing through a two inch ring."

Fig. 10a Pilot Snow-plow and Flanger.

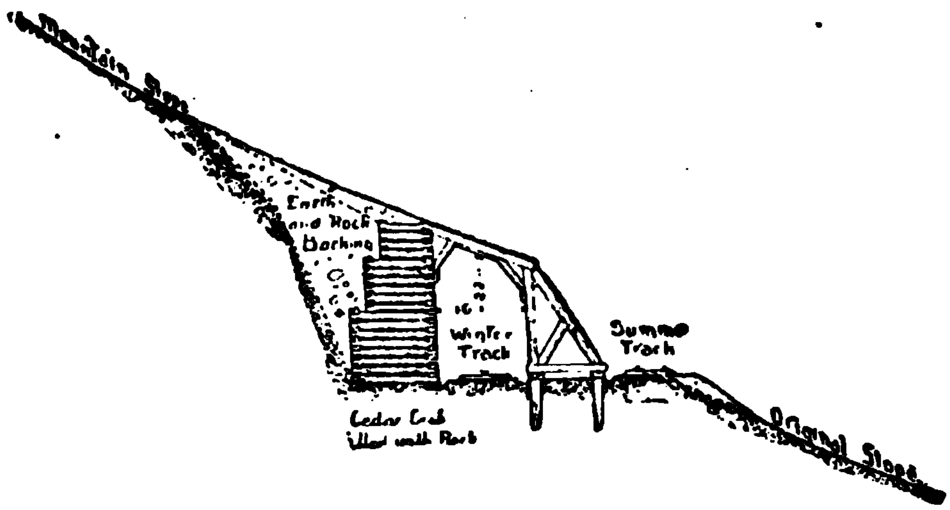
Fig. 10b. The "Rotary" Snow-plow.

Relative to the problem of removing snow, Mr. Zollinger says: "The removing of snow a sufficient distance away from the track is the greatest problem roads in the northern tier of the states and southern Canada have to contend with. In these latitudes, heavy snowstorms are sometimes of almost daily occurrence and with four or five months of continuously freezing weather, the snow does not have a chance to melt. The first few storms cause no particular trouble, for the rails are kept clear with ordinary snow-plows and flangers, but when the snow becomes walled up on each side of the track, the plows and flangers going through and cleaning out the fresh snow simply throw it against these snow walls from which it falls back in the track. When such a crisis presents itself, an army of men are called out with snow shovels to do the work by hand. On the R. W. & O. Division of the New York Central R. R., a type of plow called the Russell plow is used for cutting back these walls of snow. The device is a very heavily constructed car, usually built of southern pine, about twelve feet high. The front, which cuts the snow and throws it aside, looks like a giant dirt plow. On each side of the car are heavily built wings which can be let out or pulled in as desired by application of air. When these wings are fully extended they reach out on each side about six feet from the body of the car. They have just the proper curvature and angle to curl the snow up and shoot it clear of a snow bank twelve or fourteen feet high.

"In the west, in the mountain districts, snow-sheds are built to keep the avalanche of snow and ice from burying the tracks. These sheds are made of logs and boards

and the trains run through them as in tunnels. They are broken at intervals to check fire, should it occur.

"After ordinary snows or after the road is opened by plows, the track men are required to remove all the snow from the inside of the rails the width of a shovel. This is known as 'flanging' and is necessary to prevent ice forming against the head of the rail to such height as to derail a wheel and also to prepare for the next storm.



Snow-shed in the Sierra Nevadas.

"There is a device called a 'Flanger,' or a 'Flange Car,' which is used on some railroads and does mechanically the work of hundreds of men. It is simply a box car made over and has a blade or scraper that can be lowered between the two rails. This blade is usually lowered and raised by simply turning a lever which puts on an application of air and works on the same principle as the air-brake."

The "Flanger" is hauled over the road by a locomotive and the faster the run the quicker the road is flanged and the farther away the snow is thrown from the track.

The advantages of good drainage from the roadbed being apparent, we will next consider ballasting in rela-

tion to maintenance. The quality and arrangement of ballast materially affects the preservation of the tie from decay. But ballast has other equally important purposes besides that of drainage. It serves to increase the bearing surface of the tie and so helps the distribution of the weight of the train and lessens the force of the impact of the heavy hammer-like blow of the locomotive drivers upon the joints or ends of the rails. It strengthens

Fig. 11. Track Laid Ready for Surfacing.

the roadbed and protects the sub-grade Increases the elasticity of the roadbed, rendering it more uniform. Admits of lining and surfacing being done, also renewals being made without disturbing the sub-grade.

The recorded experience of railway track officials tends to prove conclusively that clean, sharp sand or

gravel ballast "makes a good, unyielding foundation for track," and, as Mr. Moses Burpee, in his series of letters to his trackmen, which were published in the Railway and Engineering Review, says: "Water drains through and from clean gravel or coarse sand very quickly, less quickly through fine sand, very slowly through the finest; while clay, which is composed of the same material as sand only it is ground to an extreme fineness, nearly always contains a small amount of moisture. But while it parts with its moisture very slowly it also absorbs it very slowly." Loam absorbs it quickly and retains it much longer. Local conditions and other considerations often prevent the use of an ideal

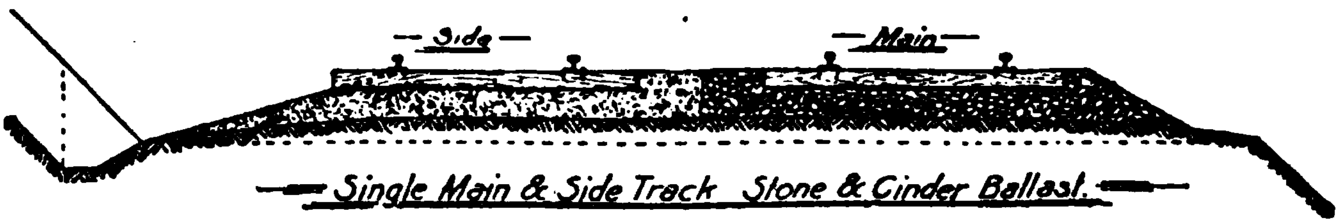


Fig. 12.

material for ballasting, therefore we will consider the uses and advantages of the different ballasting materials generally used, which, as a rule, are as follows: Rock or crushed stone, gravel, slag or furnace refuse, disintegrated granite, cinders, burnt clay, sand, chatts, volcanic cinder, burnt shale or mine cinder, earth and mud.

Mr. A. G. Caldwell, formerly lecturer on Railway Maintenance, University of Chicago, and now a railway civil engineer, on one of our railways, says: "Rock ballast is perhaps the best for the following reasons: It is very porous and allows the best of drainage; it does not heave in freezing weather, provided the roadbed is properly drained and the loads upon the ties are

more evenly distributed. Moreover, rock ballast is clean and devoid of dust and when carefully dressed presents a neat appearance. The absence of dust is a strong argument in its favor with roads depending upon summer traffic for both passenger and freight. But it is expensive to handle, in both the cost of first placing in the track and afterward for renewal. It is also harder on the ties than a softer ballast. The largest item of expense is chiefly in the cost of crushing. It has to be selected with care, otherwise there is danger of its decomposing when exposed to the elements. Sandstone will often do this, though the Norfolk and Western has used a quality that gives excellent service. The most suitable is said to be trap, granite or limestone, as they

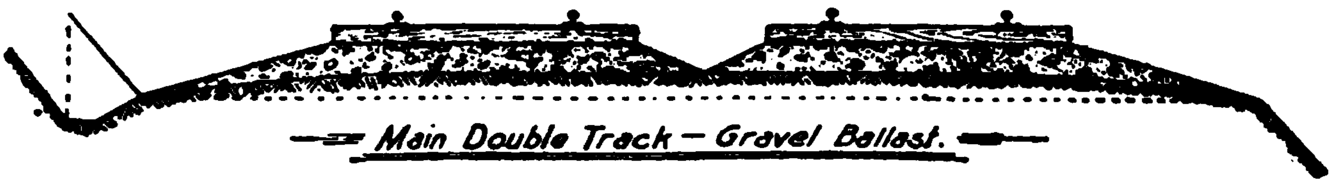


Fig. 13.

break off angularly and hence will hold together better.

"The next kind in importance and by some placed first, is gravel. For cheapness of handling, gravel is much superior to crushed rock. The chief saving being in loading the material and working it to the proper shape for ballasting. In the first place, rock requires blasting to loosen, but gravel is usually loaded by a steam shovel directly into the car. After blasting rock but little of it is of good size for direct ballasting and must be worked over in a rock crusher. This of course requires time and money. Gravel is of many kinds and is classified mainly by the size of the stones or pebbles and its freedom from earth or loam. This last point is a most

important one. The presence of rich loam or dirt is inducive of a rapid growth of weeds and grass. Unless this part of the gravel is removed, in some manner, the presence of weeds and grass will be most persistent each year to the detriment of the life of the ties and the good appearance of the roadbed. The best gravel to suit all around conditions should contain from thirty to forty-five per cent sand. When the proportion of sand is much over the upper limit the roadbed becomes dusty, to the detriment of the increase in passenger traffic and the condition of the equipment. Probably the only advantage of such ballast is a good temporary surfacing, as for the time being this sandy ballast packs well and the track can be brought up to a nicety. On the other hand a lack of sand below about thirty per cent is a most undesirable condition in ballasting. As usual in such cases, the rocks will average a large size and be entirely unfit for holding the track to line. Stone should be discarded that will not drop through one and one-half inch or two inch mesh.

"It is difficult to prescribe exact specifications for good ballast owing to the large number of varieties and the many conditions of circumstances which the product of any pit may meet. There is usually a method of overcoming the evils mentioned at a nominal cost. On some roads, ballast is screened to the proper requirements by a machine which is nothing more or less than an elevator with a series of revolving screens which separate the sand and cleaned gravel. Another process is that of washing the ballast. The gravel is elevated as before and then dropped through a series of screens while water is turned on the gravel as it enters the top screen. By an inclined arrangement the cleaned ballast

is dropped off to one side into cars placed to receive it. The water with the sand in solution is carried to the other side, where a combined weir and puddling arrangement allows the water to pass on, and the sand drops down into cars waiting below. Among the varieties of gravel with which roadmasters have to deal in certain localities is one kind known as 'cementing gravel,' a peculiarity due to the intermingling of iron oxides and calcerous material with the original gravel. It is hard to work, and when dumped off ballasting cars and sometimes after it is put in the track, forms cakes rendering it often more difficult to work than crushed rock. When possible, material of a free nature is often hauled a considerable distance in preference to using 'cementing gravel.' By mixing with it free or good gravel it is found to be of sufficient quality for track work. The amount of 'cementing gravel' except when entirely unavoidable should not be greater than one-third of the entire mass.

"A ballast which is claimed by several western roads to be superior to either crushed rock or gravel is known as 'decomposed granite.' The Union Pacific has its entire main line ballasted with this material obtained for the greater part from the great Sherman Hill, Wyoming. It is in extensive masses of decomposed granite particles and of such a nature that it is loaded direct on cars with a steam shovel. Blasting facilitates the work, but is not absolutely necessary. The Rock Island has also used it on their Colorado Division, obtaining it from Apel, Colorado, on the Colorado Midland, with excellent results. However, theirs is of two kinds, one wherein the particles are about the size of a pea, the whole having a decided pink color, the other being slightly larger in

size, the pink color being over-shot with a grayish cast. It has firmness of bearing for ties, allows the track to be easily lined and surfaced and affords excellent drainage.

"For what we might term second-class ballasting, cinders come first. In yard, commercial spur and all side-track work it is a cheap and effective ballast. Cinder ballast is also useful as a foundation for other kinds of ballast, especially in wet clay or dirt cuts.

"Furnace slag makes good ballast and is usually available for the cost of hauling from the furnace. Some slag, especially that having large porous pieces, is not desirable on account of the difficulty of handling in track for surfacing or renewal work. The preferable quality is in small, hard and glassy pieces.

"Another ballast meeting with favor in the southwest is burnt clay. The best of this kind is produced by the burning of 'gumbo' or 'black wax' clay. This material should be burned very hard, as it easily breaks up. Where this ballast is used to any extent, the kilns are often from one-half to one mile in extent over a trench previously dug to a depth of about 8 feet. The cost of burning ranges from 25 cents per cubic yard upward, though contracts have been known to be let at 19 cents, the railway company furnishing the material. The life of a tie is said to be increased ten per cent when this ballast is used, as against crushed rock.

"Volcanic cinder has been used by the Santa Fe on its Arizona lines. It is worked from pits or pockets like gravel. In appearance when in the track it resembles burnt clay.

"We must consider sand among the poorer classes of ballast. The chief trouble being its shifty nature and the damage it causes by working into axle and journal

bearings. It is used to quite an extent, however, but for the most part through lack of convenient places from which to secure better ballast such as gravel or rock.

"Burnt shale, where the shale is of the easily handled or soft variety, mine cinder and chatts are also used as ballast, but to such a small extent as to be hardly worth noticing.

"The worst ballast the section foreman has to contend with, which is really no ballast at all, is mud. In rainy weather with this material, the track becomes a sort of floating dock for trains. Its action on the tie, due to lack of drainage, is naturally severe. As a result the tie is never quite dry on the sides and bottom and with a hot sun beating down on its top, rotting quickly sets in as a consequence."

Coming to the methods of ballasting, another authority upon the subject writes: "The method depends to an extent upon the character of the work. This also determines the kind of track gang to be employed. If the work is to be done on an extensive scale such as changing an earth road-bed to one of gravel, rock, or slag, it is done by special gangs, but when merely repairs on a small scale are to be made they are done by the regular section gang.

"If an earth roadbed is being changed to one ballasted with other materials, the earth between the ties and at the ends of them should be thrown out on the slopes of the embankments. In cuts it should be removed entirely and taken to fill out narrow embankments with a view to getting the roadbed as nearly as possible to standard before beginning to place the ballast."

Methods of loading cars have been previously touched upon, the steam-shovel being most generally used.

Ballast is loaded on flat-cars fitted with side-boards, gondola or flat-bottom cars and the hopper-bottom style of cars. Flats carry from 5 to 12 cubic yards, the gondolas and hopper-bottoms varying from fifteen to thirty yards according to capacity.

For the speedy and economical handling of ballast, special cars have been designed and are being more and more extensively used, particularly where work has to be done upon a large scale. The Rodgers ballast car dumps the material between the rails in the center of the track, the last car in train of ballast cars having a plow for

Fig. 14 Rotary Dump Car.

cleaning and flanging the track. The amount of ballast to be distributed is regulated by the amount of opening given to the doors of the hopper in the bottom of the ballast car and the speed of the train. When a large amount of ballast is to be deposited, it is done by running the ballast train over the track two or more times.

Another car for handling ballast is the Goodwin Steel Gravity Dump Car. It is dumped by one man by means

of compressed air, which operates to move the dumping attachments of all the cars in the train at the same time. The ballast can all be dumped on one side of a rail or both sides, or all on the outside of both rails or all on the inside of both rails.

The latest development in ballasting cars provide for both side and center dump work. The earlier designs which are for the larger part in present use, are the separate side or center dump cars.

The Lidgerwood Engine for unloading ballast is meeting with much approval. A large center plow is placed on an empty car and at the far end of the engine of a

Fig. 15. Right and Left Hand Dump Cars.

string of loaded cars. The Lidgerwood Engine with cable and drums being on a car placed next to the locomotive. In stretching the cable, two upright posts are generally placed near the track, one on each side and far enough out to clear any swinging car doors, etc. A heavy rope from ten to fifteen feet long is attached to the top of each post and the outer ends are either attached to a ring or have separate rings to hold a hook in the end of the cable. The locomotive places the Lid-

The 25-ton (Full) Rapid Lidgerwood Unloader.

gerwood car so that the end of the cable on the Lidgerwood is close to these posts. The cable is then attached and the locomotive is sent ahead till the end of the cable can be easily caught on the large plow at the end of the train.

In distributing the ballast after the cable has been properly stretched, a flagman is stationed on top of the plow to signal both the locomotive and the Lidgerwood.

Fig 16. Making "Fill" from Trestle.

He holds flags of two different colors, usually red for the locomotive and white for the Lidgerwood. As long as he holds these up or even straight off to the side the two engines are kept in motion, but at the drop of either that particular engine stops. The reason for this is obvious. The locomotive is rarely run at the same speed as the Lidgerwood and requires separate attention. When the plow is being moved toward the Lidgerwood and

throwing the material off to the sides of the car, there are often places where more ballast is needed than others. This is especially true in reballasting work, hence the need of two flags.

Track jacks are used, one at each rail, opposite each other, for lifting the track six inches at a time when placing ballast under the ties. They are made with long narrow bases to enable them being placed between the ties. Another device for the purpose is the "Walters' Ballast Placing Device." It is maintained that for gravel, dirt, cinders, burnt clay and similar ballast this device is admirably adapted; for rock ballast it is impracticable unless fine screenings can be used to put under the tie.

In general, ballasting material should be procured at points along the road where its removal would benefit by widening cuts, reducing grades or ditching. The Northern Pacific rules provide as follows for ballasting: "All spikes should be driven before ballast is distributed; ballast should not be distributed until roadbed is of full width and all unsuitable material removed. When material is unfit for use as ballast, it should be cleaned out from bottom of tie and used for widening the banks. Where there is trouble in heaving, or wet spots, the material should be taken out to such depth and in such a manner as to insure perfect drainage. Care must be taken to avoid wasting ballast down the sides of slopes, or otherwise. The depth of ballast will be determined in accordance with the local conditions and the character and the amount of ballast already in place, if any. In general, not less than 8 inches of good material will be required under ties.

Tamping.—Tamp the entire length of ties on new track. Special pains should be taken to insure thorough tamping, from end of tie to one foot inside of rail. On old track, the center should be filled and lightly tamped.

Tamp joints and second ties thoroughly. Thorough tamping of the second tie from joints is of equal importance with that required by the joint ties, and will prevent the formation of cracks starting from upper edge of splices by reducing the upward deflection of joints when a wheel is over the second tie.

Material for filling and ballasting must not be taken from slopes of embankments. When ballasting is completed the track must be in perfect line, surface and gauge, in accordance with the stakes furnished by the engineer.

Ballast Cross-Section.—Rock ballast should be filled in level with the top of tie from center to 2 feet outside of rail, slopes 1 to 1.

Gravel ballast must be finished to the standard cross-section, which is as follows:

At the center and for one foot on each side thereof, the top of ballast will be even with the top of ties, and thence carried out with a straight uniform slope, passing four inches above bottom of ties at ends, to a point 2½ feet outside of rail, thence to an intersection with the roadbed, with slopes of 1½ to 1.

If material is used which is more or less impervious to water the slopes should be carried to an intersection with roadbed on a line with bottom of ties at ends.

The practice of crowning the ballast above top of tie at center causes dusty track and rots the tie at the center, and is not permitted except when absolutely required for

drainage on account of the character of material used for ballasting.

Ballasting is an important factor in making a good track, but in connection with it, there are other things to be remembered, concerning which a noted writer of authority, Mr. Benjamin Reece, says:

"The province of labor is to make the track stable, and to securely fasten and unite its parts so as to prevent independent motion. The elasticity of bearing does not imply loose and shifting parts. Flexibility of material must not be confounded with yielding and inadequate support. The impact due to low joints, bad surface, poor line and defective gauge greatly augments the destructive effects of increased wheel pressure, and the deterioration of track is much accelerated when deprived of proper care. In nothing do trackmen need to be more fully drilled than in the matter of thorough and conscientious track work, more particularly in tamping, so that the track may stand the service to which it is subjected. Thorough track work implies tight joints, the use of track level, true gauge, and conscientious tamping and attention to minor details."

One writer says: "There are varying opinions as to the cross-section depending upon the quality of the material and the climatic conditions. Thus with good, clean, coarse gravel, or in warm, dry regions, it is better to make the section as with broken stone, bringing the ballast level with the tops of the ties and shouldering it out 6" to 12" from their ends. With inferior fine or loamy gravel (and this is the quality most generally met with) or where water and frost have to be considered, it is better to slope the ballast from the middle of the tie

to the ends, to allow the water to drain off and not to be held back by the rails, the ballast being one inch clear below the rail base. The slope may be made continuous with that of the roadbed to the ditch, and may be to the bottom of the end of the tie or a little higher, so as to leave part of the end embedded, but this latter arrangement is likely to retain water along the ends of the ties. In some cases the ballast is flat on top for about three feet, and then slopes down under the rails to the bottom of the ties. Fine gravel is sometimes filled in two or three inches above the ties at the middle, but in wet country this keeps the ties damp and leads to rotting, though in dry country it may protect them from the sun and from hot engine cinders. The Houston and Texas Central Railway fills in the gravel between the rails to the level of the under side of the rail heads. On double track the ballast is usually sloped towards the middle of the roadbed to form a central drain which should be at least six inches below the ties, and is sometimes carried down to the surface of the roadbed. Cross-box drains in the ballast carry the water to the side ditches. At stations on the Southern Pacific Railway the ties rest on 8 inches of ballast, and cinders are filled in nearly to the under side of the rail heads between the rails and between the main and side tracks."

The maintenance work to be done and the facilities for doing it depends more or less upon the section of the country in which the railway is located and also upon the season of the year. In "Railway Track and Track Work," Mr. Tratman says:

"As to the seasons for doing the different kinds of work, it may be said that general improvements, tile

drainage, reballasting, etc., can best be carried on from late spring to late autumn, but all such work should, as far as possible, be planned and arranged for beforehand, so that the track may not be disturbed for reballasting just after the section gang has completed a thorough surfacing. Work trains and floating gangs for ditching, ballasting, widening cuts, etc., and special gangs on new interlocking plants, rearrangement of yards, repairing or building structures, etc., may be worked at any time from the end of one winter to the beginning of another. For the ordinary work on the sections no set rules or program of procedure can be formulated, as the requirements vary in different sections of the country. In general, however, the year may be divided into four seasons, and the work done during these seasons practically as outlined below:

"*Spring.*—As soon as the winter is over, all likelihood of snow passed, and the frost coming out of the ground, the work of reducing and removing the shims should be commenced. The frost will, of course, remain longer in the roadbed in cuts than on exposed banks. Low joints must be raised, spikes driven, bolts tightened, cattle guards and road crossings cleared and repaired, ditches cleaned, fences repaired, portable snow fences taken down and piled, rubbish and old material cleared from the right of way, and the necessary lining and surfacing done to put the track in good condition previous to the more extensive work later in the season. At the same time sign posts and telegraph poles are straightened, fences repaired, and side tracks and yards overhauled. The gang (if not already increased) is then increased to its maximum number and the work of renewing ties is

commenced, the ties having been previously distributed on the section. About four days a week should be spent in putting in the ties, all ties being fully tamped as soon as they are in place. The other two days are spent on other necessary work. On some roads the tie renewals are done quickly at the beginning of the season, while on others, this work is spread out through the season. The former is by far the better plan, as the continued disturbance resulting from the latter plan is very detrimental to the maintenance of good track. When the ties are all in, the work of thorough lining and surfacing preparatory for the heavy summer traffic is commenced. The lining is done first on account of the bad line resulting from the tie renewals, but the surfacing should follow very closely. The gauging is done at the same time. Ballasting is done after the new ties have been put in. In surfacing, care must be taken not to raise the track too much, but only to give a uniform surface, the track being raised out of a face only about once in four or five years.

"*Summer.*—Besides the work of surfacing, rail renewals may be done at any convenient time between spring and winter. The new rails are sometimes laid before the ties are renewed, but it is better to put the ties in first and have them thoroughly tamped up, especially if there are many bad ties. A general inspection of spikes, bolts, nuts and nut locks is then to be made. All worn, bent, broken or improperly driven spikes are removed, the holes plugged and new spikes are driven. Broken or loose bolts are made good. Switches and switch connections, frogs, guard rails, etc., need to be carefully inspected and repaired. As fast as the regular

surfacing is completed, the ballast should be dressed to the standard cross-section, and the toe of slope lined to a 'grass line' about 5 feet 6 inches from the rail. Tile drainage, correction of signs, and the general work not interfering with the track itself can best be done during the summer. Spare time can also be spent in trimming up yard tracks, and clearing yards and station grounds.

"*Autumn.*—Weeds should be cut at least once a year and the best time for this is just before seeding. The grass on the right of way should be mowed, bushes cleared and trimmed, and in cases where fires cause trouble, a fire guard may be formed by plowing a narrow strip about 50 feet on each side from the track. Burnt or decayed trees likely to fall near the track should also be removed, and the dry brush, old ties, etc., may now be burned. Old material should also be cleared up. About a month before the commencement of the winter or rainy season a general surfacing, lining, gauging and dressing of the track should be done, starting at the farther end of the section and working steadily to the other end.

"The track itself should be put in condition at the same time and the spikes and joints seen to. When this is done ditching must be undertaken, the ditches being cleaned out and improved where necessary to give the necessary width and grade. The more thoroughly this work is done the better will the track be during the winter period. Trenches should also be cut under switch rods to prevent water or snow collecting around them and freezing. The culverts and water-ways must then be cleared of brush and obstructions, and any signs of scour or undermining looked for, while streams should

be examined above and below the culverts and any obstructions removed. After this there is plenty of work to be done in cutting and burning weeds, repairing fences, repairing and erecting snow fences, and stacking additional portable snow fences where they will be needed. Track signs and telegraph poles have to be inspected and cattle guards and crossings cleaned up. Yards and side tracks may be profitably cleaned, drained, leveled up and repaired before the snow falls.

"*Winter.*—The winter work with reduced track forces is largely that of inspecting the track and making small repairs; also looking after the spikes, bolts, frogs and switches. Such work will occupy the time between snow storms or in fine weather. During snow storms the switches, frogs and guard rail flangeways must be kept clear as also all signal and interlocking connections. Salt is used to melt the snow but oil afterwards should be applied to all moving parts, such as slide plates, bell crank levers, etc., as the salt water has a tendency to rust the iron, making the parts move hard. In heavy snow storms the section men must work in clearing the track and help the snow gang or shovelers. In the intervals of fine weather, rails, ties, lumber, fence material, etc., may be distributed, ready for spring work. Heaving of the track by frost is now to be expected and proper precautions must be taken to keep the track in surface by shimming, while in very bad places blocking may be necessary. The ditches should be examined as soon as any thaw sets in and kept clear of ice or packed snow so as to allow free passage from the water."

Mr. Kindelan, in the "Trackman's Helper," thus describes "Shimming";—

"When the ballast is frozen in the winter it cannot

be tamped and if the track is heaved by frost the surface is made uneven both transversely and longitudinally. This must be tested by a level for the former and by sighting or the use of a long straight-edge for the latter. In such cases wooden plates or shims must be placed between the rail and the tie to bring the rail up to proper surface. The upper face of the tie should not be adzed to lower the rail, unless this is absolutely necessary, but the shims should be placed on the lower ties. Shimming is also required with soft ballast, that is so soft after heavy rains that tamping is impracticable, the ballast and roadbed being so saturated that no other method of surfacing is effective. In some very bad cases, or in accidents, blocking must be used under the ties but this should be avoided when possible and the foreman must see that this blocking is not forgotten and left in place but that it is taken out when the shims are removed or when the ballast has dried out sufficiently to give the track a proper bearing as the frost comes out of the ground and the ground settles, thinner shims must be substituted for the thicker ones to prevent surface bending of the rails. The shims should never be left in place after the spring; and as fast as they are removed the spike holes in the ties should be properly plugged. Heaving is most troublesome in earth and clay but is also felt in gravel. Where much trouble is experienced from heaving, it will usually be found economical to apply gravel ballast liberally; as the spiking and shimming injure the ties and spoil the permanent surface of the track. The shims may be cut by the section men but it is better to use those cut by machinery having two spike holes bored diagonally opposite one another. They are about six inches wide and the length should be at least equal to

three times the width of the rail-base so as to give ample room for spiking and keeping the spikes clear of the angle-bars. The thickness is from three-quarter inch to two inches. If a raise of more than two inches is required, a piece of one inch to three inch plank should first be spiked to the tie by bolt-spikes, the plank being about two feet long or as long as the tie if both rails have to be shimmed. Upon this plank should be placed shims to bring the rail to the required level, these being fastened by long spikes passing through shims and plank into the tie. With specially high shimming it is well to place rail braces outside the rails, especially on curves. Where tie plates are used, the plates should not be taken off, but the shims placed on them, and if the shimming is high, a tie plate may be placed on its top. The tie should be adzed to give a level seat for the shims. Spiking should be attended to as fast as the shimming is put in, and if a whole rail length is to be shimmed, the joint, center and quarter ties should be first shimmed and spiked."

Policing is thus described by Mr. Tratman: "This work includes the general maintenance of the roadway in neat and proper condition and is to be attended to continually. Weeds must be kept cut and trimmed to the grass line; ballast properly dressed and sloped; ditches cleaned; rubbish picked up, and spare material properly placed. Combustible material must be kept cleared from around bridges, trestles, signal posts, etc., dirt and gravel must be removed from bridge seats and trestle caps, and care taken to prevent ballast from working over onto the bridge abutments or falling into streets below. Large loose stones may be neatly piled around the bases of signal posts, sign posts, etc., to keep

vegetation from growing. All trees that are in danger of falling on the track, or that interfere with the passage of trains, or obscure the view must be removed or trimmed. If they are on private land, and the owners object to such work, a report must be made as to the circumstances. Any interference with or obstruction of ditches, culverts, etc., by land owners must be prevented or a report made thereon.

"All old track material, or other material from cars, old ties, rubbish, etc., must be picked up and removed from the track, all scrap being carried to the section tool house to be properly sorted and disposed of. All scrap iron, lumber, etc., must be neatly piled on platforms. New material, such as rails, ties, etc., must be properly piled or stacked, and no material should be thus piled within eight feet of the track.

"Care should be taken to have a neat and tidy appearance of the section, with track full spiked and bolted, switches cleaned and well oiled, cattle guards and road crossings in good condition, fences in repair and wing fences at cattle guards kept whitewashed, ballast evenly and uniformly sloped and free from weeds, sod line cleanly cut at foot of slopes, and grass and weeds not allowed to grow too high before cutting. Side tracks in yards should also be kept free from weeds and rubbish, old paper, scrap, etc. Station grounds also must be kept neat. Signs must be upright and in good repair. Section houses must be clean and tidy with tools, track material, scrap etc., properly sorted and placed.

"Every possible means consistent with general attention to track work, should be taken to keep people from walking on or at the side of the track and from using the railway as a public path. This is specially necessary

near cities where the traffic is heavy. In such cases, where people habitually walk on the track a liberal covering of coarse broken stone or slag or even cinders may be laid upon the ballast between the rails and tracks and upon the berme at the edge of the roadway. This will soon drive off those persons who cannot comfortably walk on the ties. This matter is far too often neglected, and railways are themselves partly responsible for the habit which the public has acquired of treating the tracks as a public way."

Station Grounds and Buildings.—"In order to have a good reputation for the road on the part of the public it is very desirable that the grounds at stations should be kept clean and tidy and free from rubbish. On some roads this work is delegated to the station agent who has his men attend to it, while on other roads it is part of the section gang's work. The latter is the better plan if the force is sufficient and the work is done by direction of the roadmaster, the station agent being given authority to employ the section men for this purpose when he thinks proper. On roads having stations with lawns, flower beds, and nice grounds a special force is sometimes kept to attend to them, for instance the Boston and Albany Railway has on each of its principal divisions a gardener with five to twelve men who grade, plant and seed the grounds, and take care of them. These men cut the grass with lawn mowers and do the weeding, trimming of shrubbery, etc. They also attend to places where the banks are graded and seeded. This force is included in the roadway department. The Pennsylvania Railway also employs landscape engineers and a large force of gardeners and spends large sums of money in making and maintaining attractive grounds. As a result

it has a reputation for the appearance of its stations. Some Western roads including the Fremont, Elkhorn, and Missouri Valley Railway have adopted the policy of making a "Park" at most of the stations, sodding the ground and planting trees. It is specially important to have attractive grounds and pleasant surroundings at important stations and at junctions where passengers may have to change trains or to stop over for connecting trains.

"In all ordinary cases, however, much may be done by foremen, and station agents who are not averse to putting in a little time in improving the appearance of the station grounds. The Agents especially should see that the grounds and platforms are kept free from all papers and other rubbish. A plot of turf, cinder or gravel pathway, a flower bed, a creeper on the building or on a pile of rock-work, can be had with little trouble and have a great effect upon the general appearance of a station. The approaches and surroundings on the town side of the station should be cared for as well as the grounds on the railway side.

"The platforms should be convenient and in good repair and the fences kept in repair. Many a division superintendent and roadmaster can aid materially in maintaining a good appearance along the road by fitting up a car with brake pumps and paint tanks for painting by compressed air, the work being done rapidly and economically by a few men, and being applicable to stations, freight-sheds, ice-houses, pump-houses, section-houses, signal-houses, signal-towers, fences, signal-posts and signs, etc., and also for whitewashing cattle-guard fences, interior of sheds, etc.

"The yards, spaces between the tracks, etc., at stations

should be neatly leveled, and covered with ashes, and should be kept in order by the section men, but strict rules should be made and enforced against the scattering of ashes and cinders from engines (which should be dumped at specific points), the sweeping of rubbish and dirt from the station onto the track, and the sweeping out of refuse and dirt from the cars upon the track. Every station should have a can or bin for waste paper and rubbish which should be emptied at intervals into a dirt car. Similar receptacles should be provided at yards or places where cars are cleaned. At large terminal-yards one man may be kept busy cleaning up paper and rubbish. It is a good plan to have station inspectors to see that the stations, waiting-rooms, closets, etc., are kept in proper and sanitary condition and that the grounds are properly cared for. Cleanliness should be enforced in every case but the standard of appearance will of course, vary according to the financial condition of the road and the size of the force. The same is true of section boarding-houses and tool-houses."

Old Material.—"In all renewals and periodical policing, cleaning up of yards, etc., it must be borne in mind that new material must be properly used and cared for, and not wasted, and also that no old material should be simply thrown away as useless. Even if really useless for railway purposes, the material in the aggregate has a certain selling value, which, if the material is thrown away, is wrongfully lost to the Company. These remarks apply also to the wreckage and scrap resulting from train accidents and the burning of cars. Record must be kept of the disposal of all scrap and old material.

"Old rails should not be left hidden in the grass or

weeds of the right of way, but properly piled for shipment as they may be used for side tracks or branches, sold for scrap or even made into new rails of somewhat lighter section by heating and rerolling. Old ties have rarely much value, but if thrown away, sold, burnt, used for cribbing, etc., all unbroken spikes should first be pulled and when ties are burned the ashes should be raked over for spikes. In piling old rails, the splice bars and bolts should all be removed, good splice bars sorted in pairs and broken bars kept separate. Nuts and bolts, if good, should be kept together, but broken bolts should have the nuts removed and kept separate. Many spikes that now go from the track to the scrap-heap (or down the bank) might be used over again if properly driven in the first place and properly drawn. Foremen should be careful to see that all track and car material, etc., is picked up regularly and that their men do not get in the habit of flinging old bolts, spikes, etc., down the bank. In removing bolts, the nuts should be unscrewed properly, the bolt taken out, and the lock and nut put back on the bolt. If, however, the nut is so rusted or wedged on the bolt that it will not unscrew, it is more economical to knock off the nut with the end of the bolt in it, with a sledge, than to waste time in forcing the wrench. Only good discipline and good management of men can insure the exercise of proper judgment as to when to knock off nuts in this way. If a wedged or rusted bolt has to be knocked out, care should be taken not to hit the head of the rail."

Care of Material.—"At the section tool-house the scrap should be piled and sorted, nuts taken off broken bolts, etc., this work being done in wet or stormy weather or when the men cannot work on the track. All scrap

iron, lumber, etc., must be piled neatly on platforms, car scraps, drawbars, couplers, etc., being kept separate. Small scrap, such as bolts, nuts and spikes may be kept in shallow boxes, or in old spike and bolt kegs. Rails may be piled on the right of way at mile-posts, but should not be piled with splice bars and bolts left on. Old ties may be stacked on the right-of-way until permission is given to burn them, the ties removed being piled at the end of each day's work and not left in the ditch or on the roadbed.

Under this heading it will be appropriate to refer to the treatment and disposal of the material found in the general scrap pile at the division points or main shops, which subject was discussed by the late Mr. J. N. Barr, of the Chicago, Milwaukee & St. Paul Railway in a paper before the Western Railway Club. 'The style of material delivered for the scrap pile is significant of the character of the men sending it, as for instance; one man who is somewhat careless and finds it easier to use new material than to sort out the serviceable from the unserviceable scrap at his tool house, will send in many old bolts and nuts that are good for further use. In some cases it may be advisable to go to the expense of putting in a set of small rolls, to bring odd sizes of iron to standard sizes for bolts, plates, etc., a shear (perhaps operated by an airbrake cylinder with 4 feet lever and 6 inch jaw) for cutting rods, or even to build a small furnace for heating angles, etc., to be rerolled. Of course, it must be borne in mind that while with a single large scrap pile at one large central shop it may be economical to carefully sort and handle the material and treat it as above noted, this may not be the case with several smaller piles at divisional shops. Also, that in

some cases an article made by treating scrap may be made more expensive than a newly purchased article of the same kind. These are matters for the exercise of judgment and calculation in order to ensure real economy.

"In most scrap piles there is a great proportion of bolts. These may be sorted as to their diameters and length and stored in compartments. Stub ends of ¾ inch to 1 inch bolts, about 5½ inches long, may be used for making track bolts, a bolt heading machine at the shops being equipped with suitable dies. Nuts may be cleaned of rust by pickling in a weak solution of hydrochloric acid and then used again, or if damaged they may be slightly compressed by dies in a bolt heading machine and then retapped. Plates and shapes may be utilized for small plate girders to cross culverts, etc. Lining bars, crowbars, wrenches, etc., may be successfully made from elliptic springs, the plate being heated to a cherry red and then put in a bulldozer, where it is sheared off and has two square holes punched at one operation. Old flues, which bring little as scrap, make good fencing for station grounds, posts for track signs, or grates for cinder pits, where fireboxes are cleaned out. Old fishplates or plain splice bars may be sheared to length and stamped to shape for rail braces.

"In sorting, care should be taken to pick out any new or practically uninjured material, which may, by accident, or carelessness have got in with the scrap, when sorted the stuff should be arranged so as to be easily seen and got at, but discrimination should be exercised so as not to store a lot of miscellaneous material on the supposition of its being of some possible use eventually." (pp 311-315 "Ry. Track and Trackwork"—Tratman.)

CROSS TIES.

Next in order we pass from the roadbed to the cross ties. The American Railway Engineering and Maintenance of Way Association gives the following definitions of a cross tie:

"A cross tie—that transverse member of a railway track which supports the rails and by means of which they are retained in position. Sawed tie—a tie having both faces and sides sawed. Half round tie—a slabbed tie which has greater width on lower than on top face.

Whole Log, Both Sides Hewn Cross Tie, Split Half Log.

Fig. 17.

Heart tie—A tie which shows sapwood on one or two corners only and which sapwood does not measure more than one inch on either corner, on lines drawn diagonally across the end of tie. A doty tie—a tie which is affected by funguous disease. Score Marks—Marks made by the axe as an aid in hewing. Face—the upper or lower plane surface of a tie."

Mr. A. C. Caldwell writes: "A hewn tie is superior to a sawed tie in nearly all cases. The reason is evident when the action of the two can be watched. As a rule the sawed tie with its sharp edges cut into the ballast, weakening the surface level and support to the rail.

The most common size in railroad ties is the 6 in. depth, 8 in. width, and 8 ft. length. Due to heavy and fast traffic this is being exceeded on some roads and more especially in the east. Such sizes as 7"x10"x8½', 7"x 8"x8½' are being used to some extent."

The proper spacing of ties, is a matter of experience rather than one of any exact mathematical formula. This is on account of the support given by ballast of so many different kinds and grades. As one of our prominent western engineers has said: "The proper spacing of ties embodies the three following features:

"1. The proper width of tie for bearing surface under the rail.

"2. The supporting strength of roadbed.

"3. The proper spacing for economical tamping.

"The first feature seems to be taken care of by widely varying methods throughout the country, naturally due to the variety of woods and the conditions which they encounter. If we stop to consider the different crushing strengths of woods we readily see the uselessness of getting a specific rule. The supporting strength of roadbed varies widely on account of the many different ballasts and their depth under the ties. This ballast question is not so difficult as the first for we can find reasonable limits to ballasting. For instance, ballast of any sort should at least have a depth of six inches under the tie and it is rarely specified for a greater depth than eighteen inches. The third feature is less important than the other two and is more a matter of convenience for using tools. We may assume 20 ties per 30 ft. rail as a maximum number, since any greater number hinders very largely rapid work in the tamping of ties."

SPACING TIES.—Regarding this matter Mr. Caldwell says: "Plenty of timber under the rails is a matter of economy and saving of rail. For main track on most roads the number is generally about 18 for a 30 ft. rail and 20 for a 33 ft. rail. In lining ties, the usual custom is the stretching of a rope anywhere from 200 to 1,000 ft., depending on the length of tangent or straight track, and at the half tie length from the center stakes set by the engineers. On curve work of any considerable sharpness the rope is staked for the tie lining at about 25 ft. intervals. A man working ahead of the rail man and chalking with a square the proper line for the base of rail can, if skillful, save considerable time. Among track-layers he is known as the 'fiddler.' He works directly behind the tie placers, who bring the ties in proper line, usually with a short pick. A matter requiring rather good judgment is the tie placing for rail joints. The general tendency is to place them too close, the idea in this being to strengthen the joint. The governing feature for the minimum distance in tie spacing is of course to allow the least space in which a shovel can be used in tamping the ballast."

Ties are spaced differently on different roads. The following table gives the spacing used to a 30 ft. rail by some of the roads in the United States:

Pennsylvania, main line	14 wide ties
" sidings	12 ties
Northern Pacific	16 "
Chesapeake & Ohio	18 "
Central Ry. of New Jersey	16 "
Southern Pacific, main line	17 "
" " branches	15 "

The joint ties should be the largest ones and should be more closely placed than the others to give a better bearing for the rail ends.

The following table gives the number of ties per mile of single track:

CROSS TIES PER MILE.

Center to Center.	Ties per Mile.
18 inches	3,520
21 "	3,017
24 "	2,640
27 "	2,347
30 "	2,112

Number of ties per 30-ft. rail, 12	2,112
" " " " " " 14	2,464
" " " " " " 16	2,816
" " " " " " 18	3,108

Ties suffer rapid deterioration from the action of the elements. Ballast and ballasting have different effects upon ties according to the material used. Where soil or clay is used sometimes the interior of ties rot before the traffic has worn them. Quality and arrangement of ballast therefore may often have a great effect upon the preservation of ties from decay.

Giving the square feet of bearing surface ties eight feet long and of different width have on the ballast or road-bed.

NUMBER OF TIES TO A 30-FOOT RAIL.	LENGTH OF THE EIGHT FEET. Square feet of surface for ties of the following width.			
	7 inches.	8 inches.	9 inches.	10 inches.
14	65.24	74.62	84.00	93.24
15	69.90	79.95	90.00	99.90
16	74.56	85.28	96.00	106.56
17	79.22	90.61	102.00	113.22
18	83.88	95.94	108.00	119.88

TABLE NO. 19.

ILLINOIS CENTRAL RAILROAD BALLAST TABLE
SHOWING CUBIC YARDS PER MILE OF TRACK

Material	Size of Ties	Double Track	Single Track		
			Class A	Class B	Class C
Rock	6″×8″×8′0″	6,891	3,488	2,692	....
	7″×9″×8′6″	7,341	3,784	2,966	....
	7″×9″×9′0″	7,496	3,916	3,081	....
Cementing gravel	6″×8″×8′0″	....	2,747	2,291	1,868
	7″×9″×8′6″	....	2,887	2,414	1,975
	7″×9″×9′0″	....	2,995	2,506	2,050
Loose gravel and cinders	6″×8″×8′0″	7,325	3,825	3,014	2,287
	7″×9″×8′6″	7,924	4,168	3,311	2,536
	7″×9″×9′0″	8,061	4,302	3,428	2,635
Earth	6″×8″×8′0″	....	....	....	499
	7″×9″×8′6″	....	....	....	541
	7″×9″×9′0″	....	....	....	551

An authority on the subject says: "Natural decay of ties ballasted with the best material, such as broken stone, gravel or cinders, would be much less than where poor ballast was used. I should think twenty-five per cent less, as a tie would lie perfectly undisturbed and dry, and would not be cut into by the rail. In poor ballast such as soil and clay, the middle of the tie would decay before its surface was damaged."

Cross Tie, Split Quarter Log.

Action of Spike on Tie. Action of Rail on Tie.

Fig. 18.

There is a great difference of opinion among practical men regarding the relative deterioration of ties from natural causes and from wear and tear. Their decay and damage are dependent upon so many contingencies that estimates of what amount should be charged to traffic and what amount to wear and tear would not apply to all roads.

One writer insists that no portion of the cost of maintenance should be charged to traffic, while another not only insists that the tie is injured by the weight of pass-

ing trains and changing of spikes, but that the movement of passing trains loosens the soil enveloping the tie, thus greatly hastening its decay.

Where the business of a line is heavy, ties receive material harm from respiking and resetting of rails, and if of inferior wood are frequently cut down and split by the rail. Ties, if properly ballasted, receive little detriment from the wear and tear of light traffic, except upon curves.

The natural duration of a tie is dependent upon the kind of wood, how it is seasoned, nature of climate, and quality of the ballast in which it is laid. All these must be considered in arriving at a result.

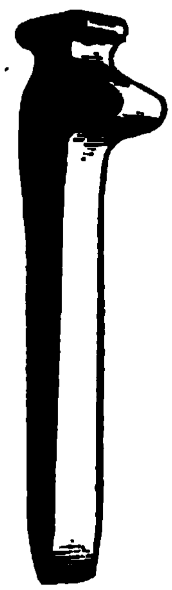


Fig. 19. Spike.

The quality of ties is important. It has a bearing on the stability and permanence of the roadbed as well as upon the cost of maintenance. Ties can be divided into three general classes as follows: 1st, untreated wood; 2d, wood treated with a preservative process, and 3d, metal.

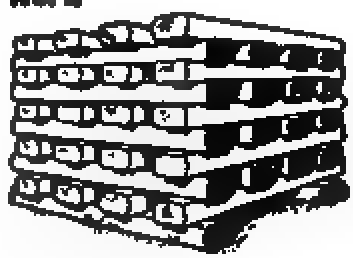
The kinds of wood vary. Statistics show the following approximate proportions have been heretofore used in the United States: Oak, 62 per cent; chestnut, 5 per cent; pine, 17 per cent; cedar (red, white and California), 7 per cent; hemlock and tamarack, 3 per cent; cypress, 2 per cent; redwood, 3 per cent; other kinds, 1 per cent.

The requirements of a good tie are: First, ability to hold a spike against the strain exerted on the spike by the rail; second, it must not be brittle and split when the spike is driven; third, the wood should not yield or be compressed by the rail; fourth, it should stand without the pressure of the ballast (when stone) without being

crushed; fifth, its size should give sufficient bearing surface to support the load imposed without the rail sinking into the tie, or the tie being pressed into the ballast, or become broken; and finally, it should be durable.

No. 1

No. 2

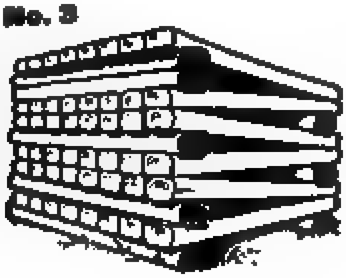


Open Crib Pile (4x4).

1. Ties must be piled in accordance with pile numbers best suited to local conditions.

2. Ground supports of sound stuff, giving not less than 6 inches clear air space, must be used, and no rotten or decaying wood allowed to remain in any yard or near any pile. In piling ties not more than two for each pile should be in contact with the ground, excepting in triangular piles, as shown in No. 1.

No. 3



——— by 4 Pile.

No. 4

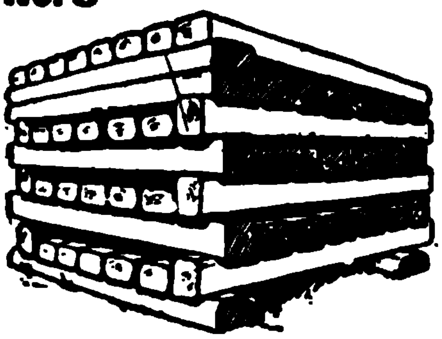
——— by 2 Pile.

3. Where roof courses are required, particular care should be taken in constructing them so as to obtain the desired protection, sufficient material necessary for this purpose being used.

4. In storage yards each pile should be plainly marked with the month and year in which received, these marks

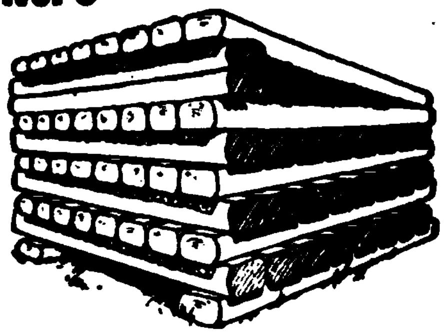
to be placed where they can most easily be seen, and a clear space, preferably 4 feet, left between each two rows of piles, to facilitate seasoning.

No. 5



Edged Pile________by________
(Outside Ties in Each Course Laid on Edge.)

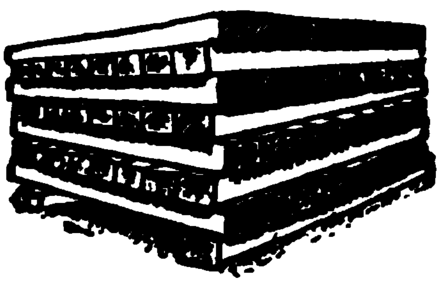
No. 6



Solid Pile________by________

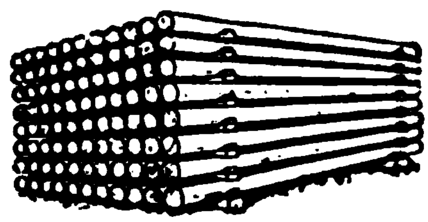
5. Material must not be piled where any part is likely to come in contact with water, or where water can stand or run on surface of ground under the piles.

No. 7



Solid Pile.
(For Cypress Ties Only.)

No. 8



Piling and Poles.
(Reverse Butts and Tops in Each Course.)

6. Tall weeds or high grass must not be allowed to remain near any material piled on the railway company's property.

No. 9

Proper Way to Lay Sawed Ties or Timber.
(Note the Year Rings all Point Downwards.)

7. Treated ties must not be placed in service until they have seasoned the full time prescribed for that purpose.

LIFE OF TIES.

	Years.
Chestnut	7
Cedar	6 to 12
Hemlock	3 to 6
White Oak, about	7
Spruce Pine	5
Yellow Pine	4 to 6
Red Wood	12 to 15
Fir	6 to 8
Tamarack	4 to 6

METHOD OF TREATMENT.

Zinc Chloride or Burnettizing.
Zinc Tannin or Wellhouse.
Zinc Creosote or Allerdyce.
Zinc Creosote or Emulsion.
Zinc Creosote or Giussani.
Creosote Ruping.
Hasselmann Treatment.
Spirit Line or Wood Creosoting.
Wood Line.
Mercuric Chloride Kyanizing.

TREATING TIES.—Concerning chemically treating ties, Mr. A. C. Caldwell says:

"Tie timber is of many kinds, such as oak, pine, chestnut, cedar, etc. The white oak tie when within fairly easy distance of a road is without doubt the best all around tie. Due to its toughness and durability it is a tie of great favor especially in the middle and southeastern states. It is much superior to the red oak, though it is an excellent tie when treated with preservatives.

Chestnut ties have a life averaging about seven to nine years under ordinary traffic and hold a spike well. Chestnut ties rot from the outside toward the center and even hold a spike when entirely rotted out on the outside. Cedar when used with a tie-plate forms a most economical tie and is a favorite over the white oak when used in the above manner.

"Treating ties with creosote and by chemicals on a number of western roads has been quite successful. One large western system has several tie-treating plants of its own and has gone at the business in a systematic way, with good results. The creosote or its modification, the 'Reuping process,' is highly successful.

"The Reuping process consists mainly of forcing air into the cells of the wood and then forcing in the impregnating fluid without dropping the pressure. The pressure used at this stage is gradually increased, varying, of course, with the nature of the wood, until a state of saturation is reached, the excess fluid being then allowed to drain off. Herein lies the commercial advantage of this process in that no more of the fluid is used than is absolutely necessary. In the equipment of the plant the impregnating and pressure cylinders are not of necessity elaborate. Two large tanks are generally used for storing the creosote after it is pumped, from a well into which the creosote has been previously run from cars. From the storage tanks, the oil is passed into working tanks, where it is brought up to the proper temperature. The creosote is then by successive steps carried through the pressure and impregnating cylinders and into the tie to be treated. By an estimate on the chemical life of the creosote it is claimed that the preservation will last from 12 to 15 years in the case of the soft pine tie. The

output of the plant is rated at 10,000 to 15,000 ties per day of 24 hours.

"There are a number of other methods of treating tie-timber such as the 'steaming process,' sulphur and various other chemical treatments. However, none of them seemed to have achieved the success secured by the use of creosote and the modified creosote processes."

A Committee on the Preservation of Timber reported to the American Society of Civil Engineers regarding the cause of decay in timber, as follows:

"Pure woody fiber is said by chemists to be composed of 52.4 parts of carbon, 41.9 parts of oxygen and 5.7 parts of hydrogen, and to be the same in all the different varieties. If it can be entirely deprived of the sap and of moisture, it undergoes change very slowly, if at all.

"Decay originates with the sap. This varies from 35 to 55 per cent of the whole when the tree is filled, and contains a great many substances, such as albuminous matter, sugar, starch, resin, etc., with a large portion of water.

"Woody fiber alone will not decay, but when associated with the sap, fermentation takes place in the latter (with such energy as may depend upon its constituent elements), which act upon the woody fiber and produce decay. In order that this may take place, it is believed that there must be a concurrence of four separate conditions:

"First—The wood must contain the elements or germs of fermentation when exposed to air and water.

"Second—There must be water or moisture to promote the fermentation.

"Third—There must be air present to oxidize the resulting products.

"Fourth—The temperature must be approximately between 50 degrees and 100 degrees F. Below 32 degrees F. and above 150 degrees F. no decay occurs.

"When, therefore, wood is exposed to the weather (air, moisture and ordinary temperature), fermentation and decay will take place, unless the germs can be removed or rendered inoperative.

"Experience has proven that the coagulation of the sap retards, but does not prevent, the decay of wood permanently. It is, therefore, necessary to poison the germs of decay which may exist, or may subsequently enter the wood, or to prevent their intrusion, and this is the office performed by the various antiseptics.

"We need not here discuss the mooted question between chemists whether fermentation and decay result from slow combustion (Erema causis) or from the presence of living organisms (Bacteria, etc.)."

Another writer says: "Various conditions affect the value of preservative processes, as shown by the wide variation of the life of treated ties. The time of year the timber is cut and the amount of moisture the tie contains when it is treated are among the known factors affecting results obtained by treatment.

"The theory of the process of wood preservation is to withdraw the moisture or sap and to introduce into the pores of the wood an antiseptic to prevent decay. The experience of the English, French, and German railroads is that pine ties are made to last from fifteen to thirty years by chemical treatment, the life depending upon the process adopted.

"The Atchison, Topeka and Santa Fe Railway officials, after more than fifteen years trial on a large scale, believe they are getting from eleven to twelve years serv-

ice from mountain pine having a natural life of about four years, while from natural (untreated) white oak they get but six years in heavy main line service, and from cedar ten years under light service."

Several other American railroads have experimented with treated ties, the results being generally favorable, many of them now treat all ties, piles and other timber used in track maintenance.

The Railroad Gazette (1907) states: "Last year 7,500,000 ties or about 10 per cent of the total number laid in track, were treated by some preservative process, according to a recent bulletin of the Department of Agriculture. Most of these ties were laid in the middle west, where the supply of hardwood timber suitable for ties has almost disappeared. Ten railroads now have their own tie-treating plants and others are planning to build similar works for their exclusive use. Straight creosoting and the somewhat cheaper process of zinc and creosote combined are now in most general favor. Mr. Octave Chanute, in discussing a recent paper by Mr. W. C. Cushing on the treatment of tie timber, warns prospective users of the creosote process against too small doses of this costly antiseptic. He gives some figures showing the life of creosoted ties on the Western Railway of France, where the process has been in use for more than forty years. Beech ties laid down in 1865 which were treated with from 40 to 48 pounds of antiseptic per tie, when taken up 25 years later, were in perfect condition. In 1878, in order to reduce the cost of the treatment, the amount of creosote injected was brought down to from 26 to 33 pounds. At the end of three years some of the ties began to decay, and after five years a large number were removed. After this experience the amount of an-

tiseptic injected was again increased to 39 pounds and later to 48 pounds as a minimum."

Mr. J. T. Richards, Chief Engineer, Maintenance of Way, Pennsylvania Railroad, stated in a lecture he delivered January, 1906: "The English roads are getting an average of twenty-one years use out of wooden ties by treating them with creosote to prevent them from rotting and by protecting them with a large tie-plate to keep the upper surface from being worn out by the rail. The life of the tie is thus extended to that of at least two or three sets of rails, or longer than our metal bridges, or cars or locomotives have been lasting, so the cross-tie should not be abandoned by reason of its short life.

"The soft wood timber used by the English roads is best adapted for chemical preservation, and can be grown to an available size within practically the life of a cross-tie. With our belt or land suitable for growing soft woods, extending from the middle of the state of New Jersey along the Atlantic Coast fifty to seventy-five miles in width to the State of Texas, it would seem to be very poor management on our part to allow ourselves to run out of wood for cross-ties."

Therefore, the question of cross-ties is not such a serious one as at first sight it appears to be. True, the use of hardwood for ties may in time be discontinued, but, as Mr. Richards says, there is no good reason why we should "run out of wood," since the use of soft-wood ties has been successfully demonstrated. By treating soft-wood ties and by the general use of tie-plates there seems to be no immediate cause for anxiety concerning an adequate supply of cross-ties for years to come.

Metal Ties. The third style is the metal tie. These ties have, for the most part, been designed after the

wooden cross-tie with such changes as seemed necessary. Metal ties have been used to a large extent in some countries where timber is scarce or decays rapidly. European practice has proven the metal tie to be economically successful under the conditions which prevail there.

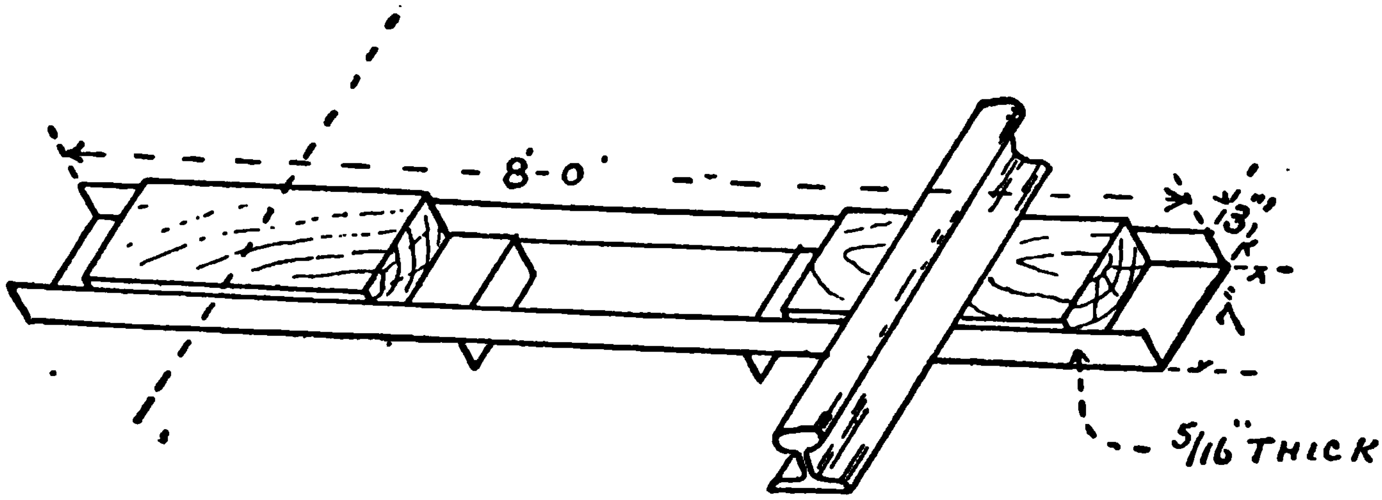


Fig. 20. Morrell Metal Tie.

Generally satisfactory experiments with metal ties have been made in England on the principal roads, with results which it is thought may lead to important developments, metal ties being more universally adopted ultimately.

In Holland and Germany metal ties are extensively used and in Belgium experiments have been made with satisfactory results. In France metal ties have not been officially adopted yet, although for some years experiments with many styles and patterns have been in progress. France has been using chemical preservatives for wood for so long and so successfully that the need for metal ties as a substitute for wood has not been as pressing as it is in some other European countries.

An authority on the subject says concerning the experience of the railways in Holland in connection with the use of metal ties that the results have been satisfactory from every point of view. "Of one hundred and

twenty-four thousand metal ties laid during a period of sixteen years not one had to be removed. Ties, after being in use for twenty-five years with a service of sixteen trains per day, have been found to be substantially as good as new. The metal track is found to be safe, elastic and agreeable."

The railways in Switzerland having the heaviest traffic have used metal ties for some years with highly satisfactory results. Experience and careful calculations have resulted in placing the minimum durability of metal ties at forty years, although it is thought it may be extended to seventy years.

The following countries have been the principal users of metal ties:

Countries.	Mileage, 1894.
British India	13,655
Germany	11,605
Argentine Republic	3,638
Cape Colony	906
Egypt	866
All other countries	4,425
Totals	35,095

The value and character of metal ties have been carefully considered and exhaustingly discussed at various railway congresses in Europe and at the last International Railway Congress held in Washington, D. C. It seems to be generally conceded that after comparing the relative cost, and taking account of every expense, including first cost, transportation, handling, laying, maintaining, renewing, interest, and the value of the old material, there

are few railroads where the exclusive use of wood for ties is the cheapest. Those qualified by skill and experience sum up the result of their observations in regard to the requirements of a successful metal tie as follows: "It must be heavy enough to hold the rails down well and make a firm track; light enough to be of reasonable cost; must have metal enough to stand wear and tear and give ample strength; must be easy of manufacture, and require a minimum of shop-work; must not be liable to lateral motion in the ballast; must be easy to lay, remove, or ballast. The fastenings must be simple and efficient, with as few parts as possible, and capable of adjustment for widening the gauge at curves, etc., the price be such as to enable an actual ultimate economy to be shown, the quality of the metal must be such as to sustain shocks without injury and it must have sufficient elasticity to give an easy riding track."

The experiments and experiences of different countries will eventually evolve a perfectly satisfactory metal tie. Out of it will grow practical forms and efficient methods. It will remain for us to profit by this experience, which will result in improvements and modifications made necessary by actual practice.

The essential advantages will prove to be, as a writer on the subject has said: "Reduced expense for maintenance and renewals, owing to the solid construction and the greater durability of the parts; a better class of track, owing to improved fastenings, etc., and the fact that the roadbed is not torn up (as with wooden ties) for frequent renewals, so that it gives the best road with the least amount of work for maintenance, and finally increased safety for traffic, owing to the superiority of the fastenings over those used with wooden ties."

Tie-Plates.—Regarding the use of tie-plates Mr. J. T. Richards says:

"With the depletion of the white oak and the harder timbers, necessitating the use of softer and cheaper woods for cross-ties, and the increase in the weight of locomotives and equipment and lading, the wear on ties at the point of rail contact has so rapidly worn them out, that it has become necessary to place a plate immediately underneath the rail for the protection of the tie. These are known as "tie-plates," which are now being more generally used with good effect.

"The function of the tie-plate is to protect the wood, and to hold the rail to gauge more firmly than the old standard spike."

As already stated, chemical treatment of such softwood ties as hemlock, mountain pine, Oregon fir, etc., materially increases their life by protecting them from decay and the effects of climatic action. This fact, however, does not remove the advisability, if not the actual necessity of using tie-plates to further protect them from damage by rail cutting.

It has been shown that the 5½ inch wide rail-base of a 100-pound rail quickly cuts into a cross-tie and so shortens its life, but recent practice has demonstrated the fact that this damage by rail cutting is obviated to a great extent by the use of tie-plates of approved standard patterns.

Where tie-plates are not used on all the ties they will be found of special benefit on heavy grades and sharp curves, preventing cutting of the tie and canting of the rail. They also preserve the gauge without the use of rail braces. In places where moisture tends to soften the tie they prevent the rail cutting into it and preserve the

gauge. Where the roadbed yields under the weight of the train, such as swampy ground, they prevent the rail from cutting into the tie, thus lessening the tendency to excessive rail creeping. They should also be used on long bridges, elevated roads, in busy freight yards and on tangents where trains are frequent, and where track deteriorates rapidly.

The uses of tie-plates may therefore be briefly summarized as follows:

1. To prolong the life of new soft wood ties by preventing the destruction of the fibers by the sawing action of the rail.

2. To prolong the life for years of rail-eaten ties, by proper adzing and the use of tie plates.

3. To give a firm seat to the rail, and hold it in an upright position, thereby maintaining perfect surface.

And, lastly, to hold the track to gauge, for the reason that the spikes are backed by the plate on both sides of the rail, both spikes being used to hold rail in line.

Many forms of tie-plates have been introduced, the first used being merely flat pieces of boiler iron with holes punched for spikes. Then came a flat bottom plate with a shoulder on top, and next plates made with under ridges cutting across the grain of the wood to prevent the sliding of the plate, and later modifications of this in the form of claws or broken ribs. This style was followed by the longitudinal flange plate, the advantages of which are thus briefly described:

First, a plate with longitudinal flange is stronger for the weight of metal used than any other form of plate. Second, the flanges bedding themselves between the fibers

of the wood, prevent the sliding of the plate. Third, they furnish the requisite supporting power to the spike to prevent the spreading of the track, and, fourthly, they attach themselves to the tie in such a way as to become a part of it, preventing friction between the plate and tie, thus preserving the fibers of the tie.

The pioneer of longitudinal flange plates was the Servis, which was afterward followed by the Wolhaupter, and next came the Q and W, a combination of the Servis and Wolhaupter.

The Wolhaupter and Q and W have come into general favor of late, millions now being in use; it is claimed for them that: First, they furnish a maximum strength, maximum life, with a minimum amount of metal. Second, the flanges are so designed as to furnish the requisite resistance against buckling. Third, the metal is distributed and arranged to give the greatest cross section of metal to resist the shearing action of the spike by having grooves over instead of between flanges; grooves between flanges drain water into spike holes. Fourth, the grooves collect the sand and dirt and prevent the grinding out of the plate.

There are three general styles of tie-plates made, of which it will suffice here to mention only the longitudinal flange already described, the "C. A. C." or claw and shoulder, the flat bottom, corrugated top, shoulder tie-plate and the combination joint and intermediate tie-plate as shown in the following illustrations:

(Patented)

Tie Plates.

Not taking into consideration the advantages of a smooth riding track, the increased life of the ties, and the prevention of spreading rails and possible wrecks, the use of tie-plates is becoming a question of economy. It is claimed that careful estimates show that the difference

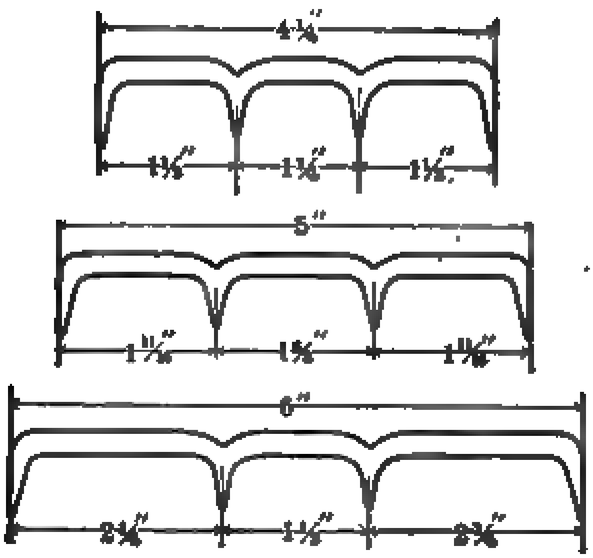
in cost between soft and hard wood ties, together with the expense of adzing, tamping and keeping track to gauge and line when using hard-wood ties, will, when soft wood ties and tie-plates are used, defray the cost of the plates in two years.

Tie Plates.

A section foreman on the C. & N. W. Ry., Mr. Geo. Samson, writes, regarding his experience with the use of tie-plates, as follows: "Good cedar ties last about eight years when the traffic is heavy and trains fast, but when tie-plates are used they last about sixteen years." This is significant when it is considered that the average life of an oak tie is but eight years; "thus," he says, "it will be seen that chestnut, yellow pine and other soft

woods will serve instead of oak ties on curves if tie-plates are used." Continuing he says: "The best way to put tie-plates on new ties is to first lay the gauge on the tie and pound the tie-plate on with a wooden sledge before the tie is pulled into the track." Where tie-plates

Sectional View



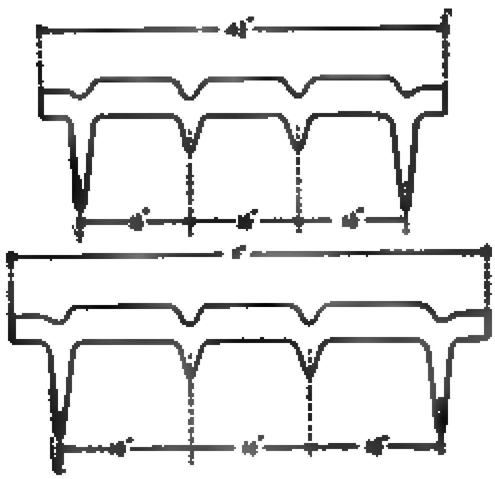
Tie Plates.

are used on hard or medium hard, fibered ties, a plate 4¼" or 5" wide, in accordance with the weight of the rolling stock and amount of traffic, should be used. On soft wood ties a plate not less than 5" wide should be used, but preferably a plate 6" wide. Under no circumstances

should a plate less than ¼″ thick be used, and where traffic is heavy, a plate 5-16″ or 3-8″ thick is necessary. Plates should be not over 3″ longer than the width of the rail-base.

(Patented)

Sectional View



Tie Plates

POINTERS REGARDING TIE PLATES.

Holes: For a 9-16″ spike allow about 1-16″ play. Holes usually are ⅝″ by ¾″. For ⅝″ spikes make the same allowance. Holes are generally ¾″ square. From outside to outside of holes should be 1-16″ more than the base of the rail and spike added. The length should be about 3″ more than the base of the rail. The width and

style depends upon the character of the tie and the base of the rail. For heavy traffic heavy plates 5-16" to 3/8" thick should be used. For average traffic plates 1/4" thick will answer. On hardwood ties narrow plates may be used, but on soft wood ties it is best to use about 5" plates, although some roads prefer the narrow plate, using a special plate at joints on account of the wide stagger of angle bar slotting. The following illustration indicates the proper names for plates, according to the ties upon which they are to be applied.

Many roads specify three holes for intermediate plates as shown by the following illustration. When so punched the confusion and extra labor in handling is avoided which often ensues when using plates punched with two holes, right and left.

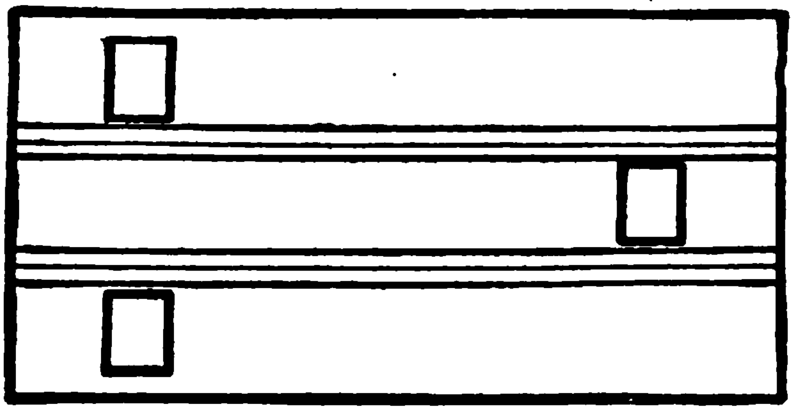


Fig. 21. Can be used on either side of the track.

When laying new rails it will be unnecessary to move tie plates if they are punched with holes for two different rail bases. The following illustration shows a plate punched for a 60-pound and 75-pound rail.

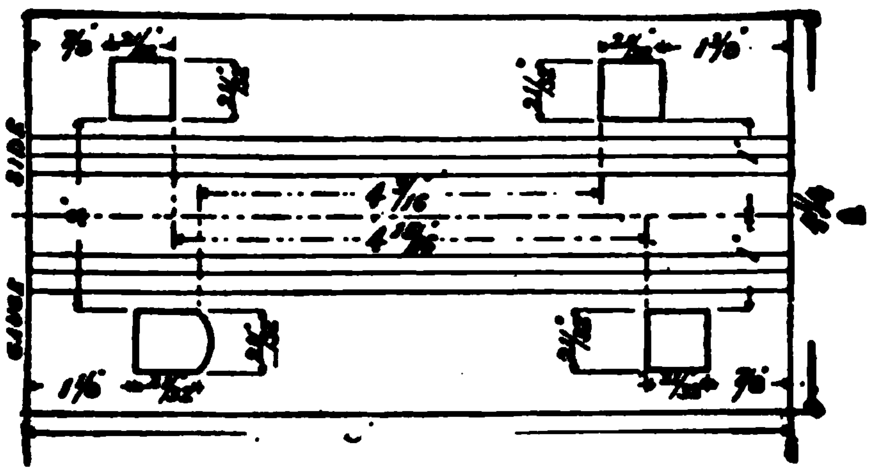


Fig. 22.

The following rules for applying tie-plates under the various methods described will be found practicable and should prove useful to trackmen:

SETTING UNDER TRAFFIC METHOD.

1st. Draw spikes on every other tie.

2nd. Plug spike holes.

3rd. If tie is cut by rail, adze it perfectly smooth, a

little deeper on inside than on outside, over a space about three inches beyond the ends of plate. Never leave adzed surface dished or hollowed.

4th. Place plate under rail exactly square with it.

5th. Drive spike straight down.

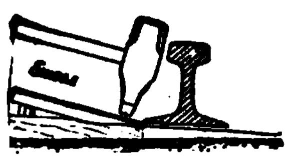
6th. After first train passes over track, drive spikes home.

7th. Go over track again and place plates in same manner on every other tie that has been left without a plate.

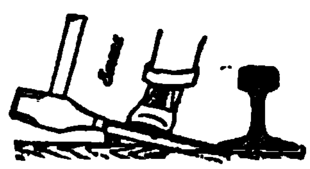
CHANNEL METHOD.

1st. Pull spikes, plug holes and adze ties same as in self-setting method.

2nd. Place plate on tie outside of rail, raising one end of plate by putting spike under it—drive flanges well down into tie with swage. See A.



(A)
Fig. 23.



(B)
Fig. 24.

3rd. Drive inner end of plate beneath rail with swage. See B.

4th. Remove spike, nip up end of tie and drive plate home.

5th. Set flanges on inner end of plate well down into tie.

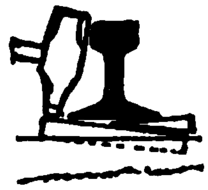
6th. Drive spikes, and then set plates on every other tie without a plate in same manner.

APPLICATION OF TIE-PLATES WITH WEDGE.

Draw spikes, plug holes, adze ties on every other tie same as in self-setting method, and place plate in position under rail.

(A) (B)

Fig. 25.



(C)

Fig. 26.

1st. Drive inside edge of plate into tie. Sketch A.
2nd. Place wedge between plate and rail. Sketch B.
3rd. Drive outside edge of plate into tie until plate is seated. Sketch C.

THE PLATE GAUGE.

Used in Connection with the Follower Plate Method.

Adjust gauge so that when plates are placed in forks they will be in proper position on tie for driving.

Drive Home with Beatle and Follower Plate.

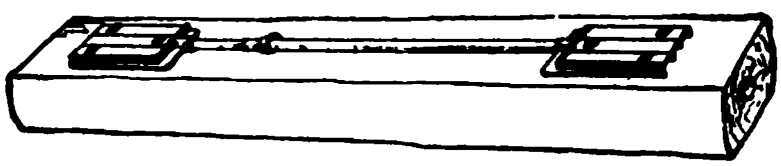


Fig. 27. Tie Plate Gauge.

FOLLOWER PLATE SYSTEM IN TRACK.

Draw spikes on every other tie, plug spike holes and adze tie same as in self-setting method of application.

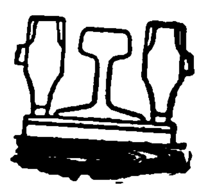


Fig. 28.

Place tie plate under rail, with a ⅜-in. thick perfectly flat follower plate on top of same. Drive plate home with swages by striking each end of the plate at the same time—until plate is seated.

STRADDLER METHOD.

Draw spikes, plug holes, adze ties, and set plates under rail properly, as in self-setting method. Place straddler in position, and strike same with 20 lb. swage until seated.

Fig. 29.

BY MACHINE.

The machine shown is an ordinary push car rigged with a small pile driver. The blow of the hammer is received by a straddler, which in turn distributes the blow evenly and without injury to the plate, seating the same perfectly in the tie.

Fig 30. Designed and used by the Southern Pacific Co.

BY MACHINE IN NEW TIES BEFORE THEY ARE PUT IN THE TRACK.

(Patented.)
Fig. 31.

Note:—The machine above illustrated is owned by the Railroad Supply Company, who lease it to railroad companies when so desired.

BY MACHINE IN NEW TIES BEFORE THEY ARE PUT IN THE TRACK.

(Patented.)
Fig. 32.

This method was used in the construction work of the Santa Fe & San Joaquin Valley Railway in California by the Atchison, Topeka & Santa Fe R. R. Co., and proved very satisfactory.

Fig 33. Wilson Hydraulic Press

This press consists of two open face jaws which exert a pressure of forty tons each. There are guides to locate the spike holes in line for the rails. It is operated by a

double plunger hand pump as shown in cut. The weight of this machine is 1,750 pounds.

Fig 34. Double Plunger Pump.
Used in connection with tie-plate press.

Sometimes it is necessary to punch special holes in tie-plates at different points along the track, for which purpose a portable tie-plate punch is used same as shown in the following illustration (Fig. 35).

The Spike.—With the substitution of cross-ties as the support of the rails instead of the stone blocks came the introduction of the railroad spike in which there has been but little change from the earliest period of use to the present time. The spike has made a great record for efficient work, but the heavy rolling loads are likely soon to crowd it out and call for a stronger device.

An authority on track states: "The holding power of the spike depends on the nature of the tie, the conditions

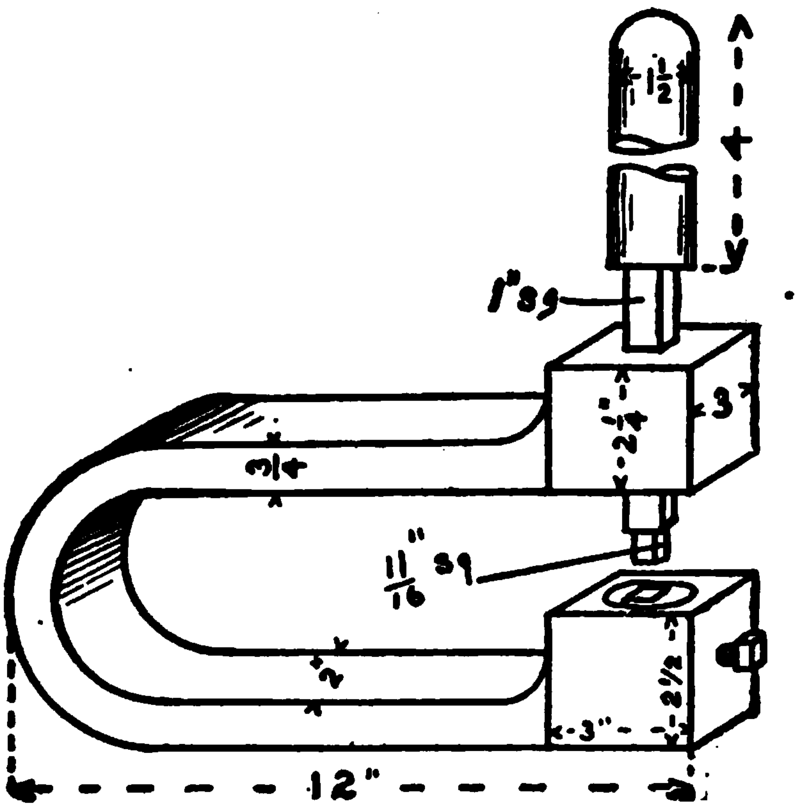


Fig. 35.

RAILROAD SPIKES

Size Measured Under Head	Average No. per Keg of 200 lbs.
5½ x 9/16	375
5 x 9/16	400
5 x ½	450
4½ x ½	530
4 x ½	600
4½ x 7/16	680
4 x 7/16	720
3½ x 7/16	900
4 x ⅜	1000
3½ x ⅜	1190
3 x ⅜	1240
2½ x ⅜	1342

Fig. 36.

under which the spike is driven, and the length of time it has been in the track.

"The force exerted by the rail when a train passes over it tends to lift the spike out of the wood; this takes place on a tangent, and is independent of any lateral pressure produced by the swaying motion of the train. The holding power of newly driven spikes has been found by experiments to vary from 1,500 pounds to 7,000 pounds, the latter being one of those cases, probably, where the conditions were more favorable than exist in actual practice. In a good oak or pine tie the resistance of a newly driven spike for a 75-pound rail would probably be about 3,500 pounds."

Spikes required per mile of track:

Size Measured Under Head.	Average Number Per Keg of 200 Pounds.	Ties Two Feet Between Centre and Four Spikes per Tie, Makes per Mile.	RAIL USED Weight per Yard.
Inches.		Pounds. Kegs.	
$5\frac{1}{2} \times \frac{9}{16}$	375	5632 = 28.16	45 to 100
$5 \times \frac{9}{16}$	400	5280 = 26.4	40 to 56
$5 \times \frac{1}{2}$	450	4692 = 23.46	40
$4\frac{1}{2} \times \frac{1}{2}$	530	3984 = 19.92	35
$4 \times \frac{1}{2}$	600	3520 = 17.60	30
$4\frac{1}{2} \times \frac{7}{16}$	680	3104 = 15.52	25
$4 \times \frac{7}{16}$	720	2932 = 14.66	23
$3\frac{1}{2} \times \frac{7}{16}$	900	2356 = 11.73	20
$2\frac{1}{2} \times \frac{3}{8}$	1342	1572 = 7.86	16
$2\frac{1}{2} \times \frac{5}{16}$	1800	1172 = 5.86	12

Fig. 37.

Damage to Cross-Ties by Spiking.—Mr. Caldwell says: "Experiments show that driving the spike, without previously boring for the same, lessens the adhesion of the spike, and injures the wood. When a spike is so driven

in an oak tie, the woody fibers are driven downward with the spike extending around the same for about half an inch, and inclining, on an average, at an angle of about 45 degrees. By removing the spike and splitting the tie

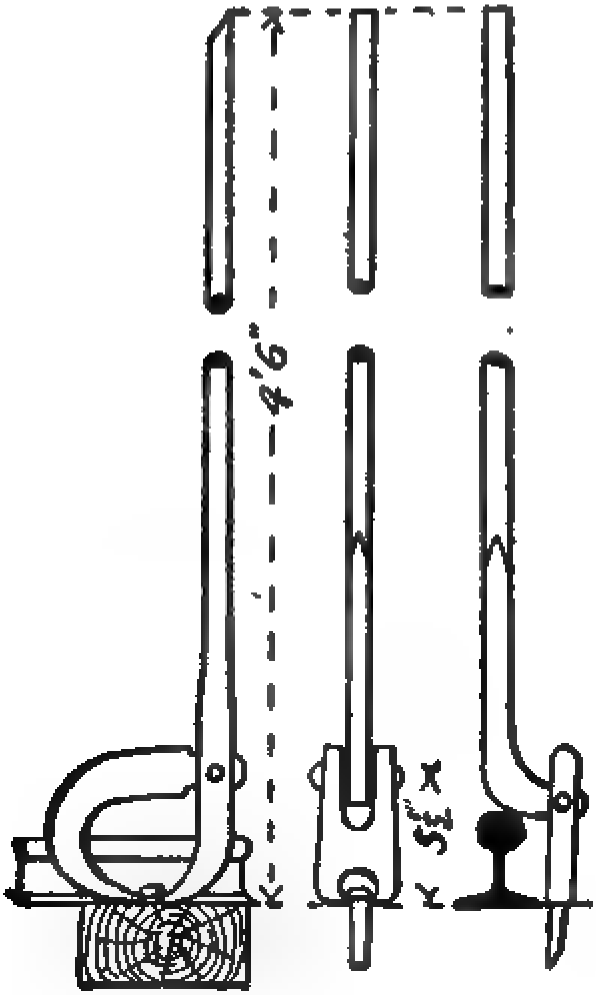


Fig. 38. SPIKE PULLERS.

A. Works on same principle as cant hook when used to turn a piece of timber.
B Pulls spike without bending.
C Pulls spikes from between guard rails, switches, frogs. Is used also on bridges.

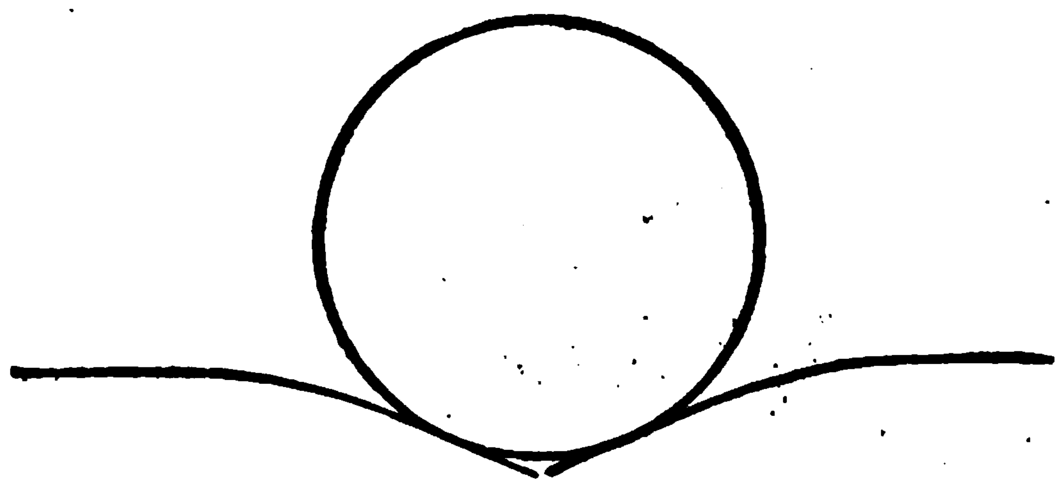
through the spike hole, it will be found that the fibers have sprung back until the hole is nearly half closed; they will also be found to be perfectly pliable, having lost

almost all power of adhesion; they are thus in good condition to receive moisture, which engenders decay. To obviate this, a hole one-sixteenth of an inch less in diameter than the thickness of the spike should be bored the full depth that the spike will be driven in the wood. This prevents injury to the fibers and increases adhesion, which latter is the principal point gained by boring holes. A spike with a diamond point will give better satisfaction than the ordinary chisel pointed spike. The ordinary spike, on account of its sharp edges, has a tendency to drift from the direction of the hole. The diamond pointed spike will go straight home. The spike should have a short point commencing half an inch from the end and tapering uniformly on its four sides. The holes should be made in ties before they are put in track."

RAILS.

"The life of first-class 60 to 80 pound steel rails was given by Wellington in his 'Economical Theory of Railway Location' (1887) as about 150,000,000 to 200,000,000 tons. There are from 10 to 15 pounds of metal, or ⅜-inch, to ⅝-inch depth of head available for wear, and abrasion takes place at the rate of about one pound per 10,000,000 tons, or 1-16-inch per 14,000,000 to 15,000,000 tons of traffic. The rate of wear is increased about 75 per cent by the use of sand by the locomotives. The failure of modern rails, as a rule, is due more to deformation of section at and near to joints than to abrasion proper, and this deformation and crushing are largely due to the heavily loaded driving wheels, the wear from which is estimated at 50 to 75 per cent of the total. Heavy freight engines may have three or four

driving axle loads of 30,000 to 38,000 pounds, on a wheel base of 12 to 15 feet. The area of contact between the driving wheels and rails is an oval about 1x¾ inch, or with worn tires or worn rails 1x½ inches, with an area of 1.07 square inch. The maintenance of rails ought not to exceed one half cent or one cent per train mile, but it is very generally as much as three cents, owing partly to work on side-tracks. About half the metal in the rail-head is available for wear, but the full depth of wear is not obtainable in main track, as the rails would then be too rough for service; about ¼ inch is the limit of wear in main track, the rails being then removed to branch or side-tracks."



Action of Wheel on Rail Joint.

Illustrating the evolution of the weight of the rail and the modern rails used by the Pennsylvania Railroad, Mr. Joseph T. Richards, Chief Engineer Maintenance of Way of that road, says: "We have had in main line tracks, rails weighing 41½ pounds per yard, afterwards increased to 45 pounds, 60 pounds, 64 pounds, and 67 pounds. Early in the Eighties 70-pound rails were introduced and used until 1887, when 85-pound rails were adopted and continued for five years until 1892, when

they gave way to the present rails of 100 pounds per yard."

Continuing, he says: "The question of what is the proper rail section, remains practically unsolved to the present day. It has been the subject of discussion by various scientific societies, as well as by the manufacturers of rails.

Angle Splice Bar. Angle Splice Bar.

Fig. 39.

"The American Society of Civil Engineers thought it important enough to appoint on June 3rd, 1885, a committee to consider this important feature of roadbed construction, and they established what is called the 'American Society Section of Rail.' This committee made its first report June 29, 1888. The rail recommended was ac

cepted by a great many railroads in the United States, but not by others. In March, 1902, the American Society of Civil Engineers appointed another committee to reconsider the subject. The American Railway Engineering and Maintenance of Way Association, the American Society for Testing Materials, and the Engineering Standard's Committee (of Great Britain), all have committees. Since 1902, these committees have been working in harmony, and with the manufacturers of rails, have obtained and discussed much data pertaining to the service of rails made by different metallurgical processes under various specifications and have also collected information as to the use by the American railroad of rails made according to the American Society Section. The following shows the percentage of the American Society Section of rail rolled by eight mills in the United States for domestic use, and similar information in regard to those for export in the totals rolled for each for the year ending June 30th, 1905:

Fig. 40. Tendency Which the Motion of the Wheel Has to Crush the Rails at Their Joint.

Tons per mile and feet of track per ton of rails of different weight per yard:

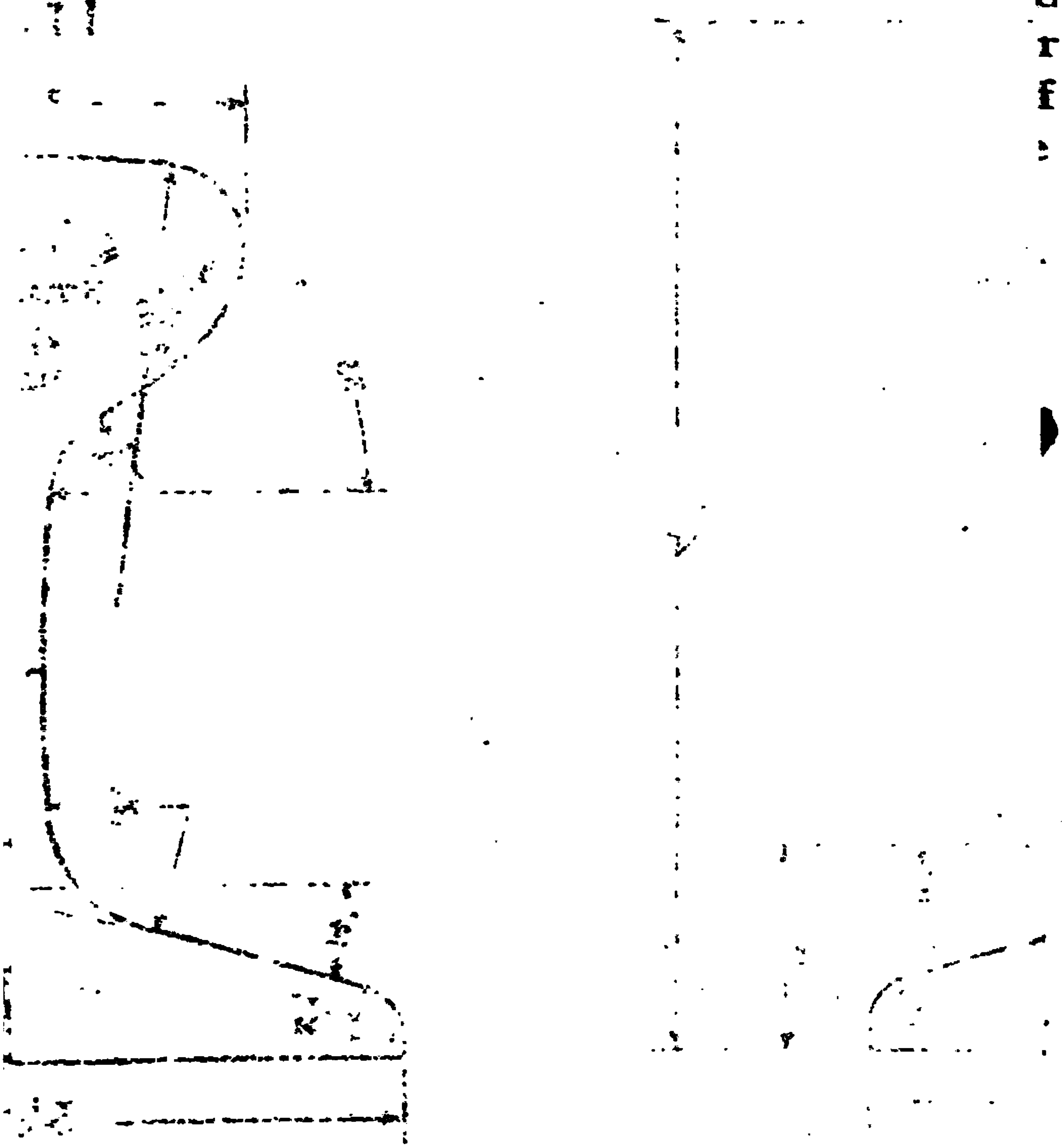
Pounds per Yard.	Gross Tons per Mile.	Feet of Track per Ton of Rails.	Pounds per Yard.	Gross Tons per Mile.	Feet of Track per Ton of Rails.
48	75.43	70.00	84	132.00	40.00
49	77.00	68.57	85	133.57	39.53
50	78.57	67.20	86	135.14	39.07
51	80.14	65.88	87	136.71	38.62
52	81.71	64.62	88	138.29	38.18
53	83.29	63.40	89	139.86	37.75
54	84.86	62.22	90	141.43	37.33
55	86.43	61.09	91	143.00	36.92
56	88.00	60.00	92	144.57	36.52
57	89.57	58.95	93	146.14	36.13
58	91.14	57.93	94	147.71	35.75
59	92.71	56.95	95	149.29	35.37
60	94.29	56.00	96	150.86	35.00
61	95.86	55.08	97	152.43	34.64
62	97.43	54.19	98	154.00	34.29
63	99.00	53.33	99	155.57	33.94
64	100.57	52.50	100	157.14	33.60
65	102.14	51.69	101	158.71	33.27
66	103.71	50.91	102	160.29	32.94
67	105.29	50.15	103	161.86	32.62
68	106.86	49.41	104	163.43	32.31
69	108.43	48.70	105	165.00	32.00
70	110.00	48.00	106	166.57	31.70
71	111.57	47.32	107	168.14	31.40
72	113.14	46.67	108	169.71	31.11
73	114.71	46.03	109	171.29	30.83
74	116.29	45.41	110	172.86	30.54
75	117.86	44.80	111	174.43	30.27
76	119.43	44.21	112	176.00	30.00
77	121.00	43.64	113	177.57	29.73
78	122.57	43.08	114	179.14	29.47
79	124.14	42.53	115	180.71	29.22
80	125.71	42.00	116	182.29	28.97
81	127.29	41.48	117	183.86	28.72
82	128.86	40.98	118	185.43	28.47
83	130.43	40.48	119	187.00	28.24
			120	188.57	28.00

	Domestic.	Foreign.
Pennsylvania Steel Co .... / Maryland Steel Company..	..82%	Practically none
Cambria Steel Company....	..77%	None
Illinois Steel Company.....	..84%	None
Carnegie Steel Company....	..69.34%	79.9%
Lackawanna Steel Company	..99.3%	Practically none
Tennessee Coal and Iron Co.	..88.6%	None
Colorado Fuel and Iron Co.	..65%	None

"From this it can be seen how largely the rail section is standardized. Great economy must result by the railroads of the United States, thus allowing the mills to produce such a large percentage of the total output from one pattern."

Regarding natural deterioration, rust, or oxidation is the greatest enemy to the rail, and concerning its destructive tendency Professor Carhart, in "Building and Repairing Railways," says:

"It is well known that a polished iron or steel surface does not rust so soon as a rough surface which is exposed to the same conditions. Rough lines and sharp points appear to serve as nuclei about which water condenses. Moist air when expanded suddenly precipitates its vapor as a cloud, if dust is present to furnish centers of condensation. Frost crystals form first along scratches on glass, so moisture appears to condense more quickly and freely on a rough surface of iron than on a clean polished one. Rusting takes place only in the presence of moisture. A clean plate in dry air never rusts. Mixtures



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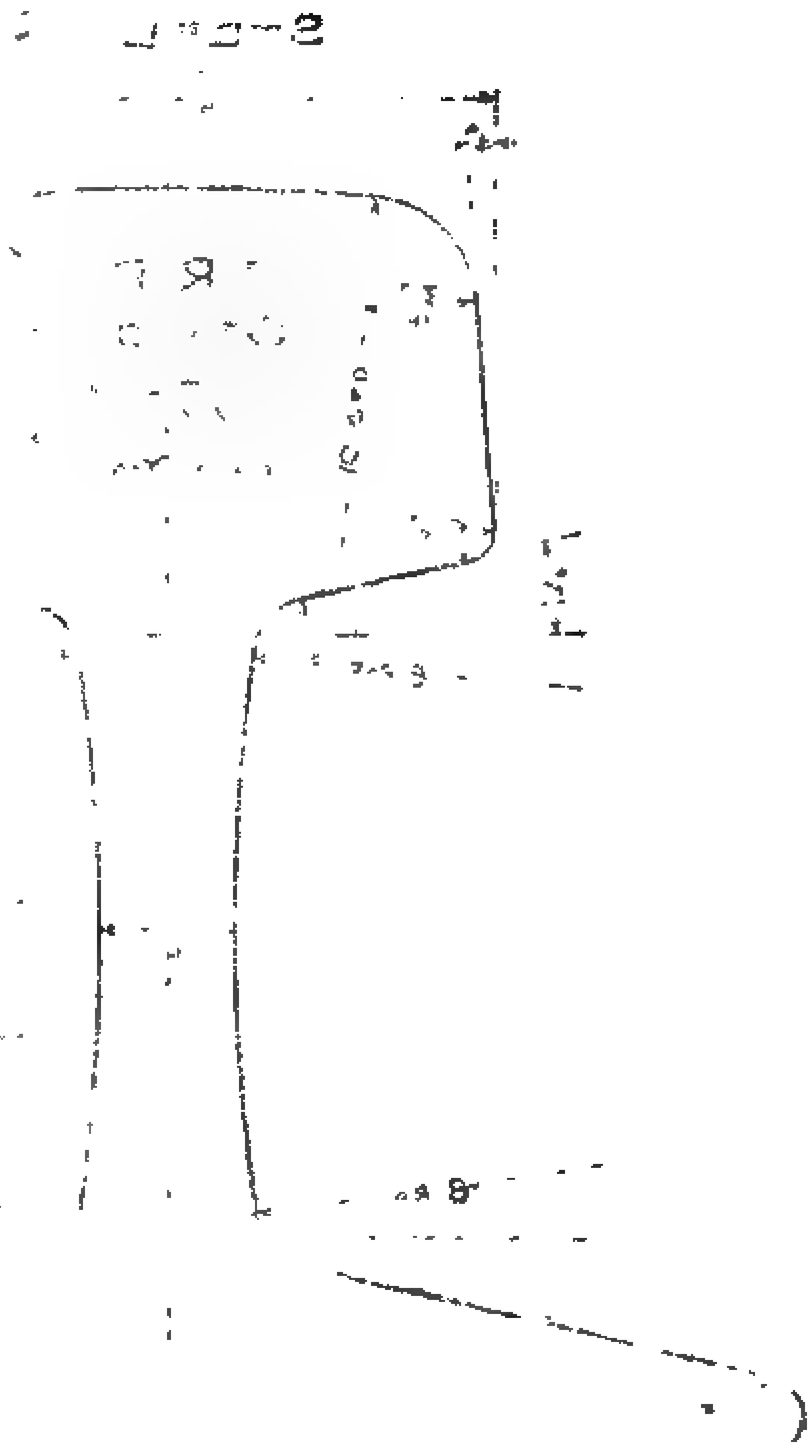

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of explosive gases do not explode when the electric spark passes unless vapor of water is present. When a metal surface is once covered with rust, the rusting proceeds much more rapidly than at first, because the rust is hydroscopic; moisture is taken up and conducted inward toward the metal; hydratic oxides of iron are thus formed and fresh metal underneath is attacked because of the presence of moisture or of the hydratic oxides on the out-

Fig. 48. Perfection Track Drill for Drilling Bolt Holes in Rails. Feed Automatic or Hand as Desired.

side. A coat of iron rust hastens the rusting process except when the metal is coated with the black oxide of iron. It can then be exposed to any weather without rusting. But the black oxide is formed only at a high temperature. The scales that fall from the rails as they come from the rolls are largely black oxide of iron."

While it is, of course, most desirable to have rails of ample weight for the traffic, and although the tendency is toward using heavier rails, yet, as Mr. Tratman says:

"The rail is only one part of the track, and that improvements in ballast, ties, fastenings, joints, etc., are of equal importance in the construction and maintenance of a first-class track. The laying of rails should also be very carefully and thoroughly done, though this is a point that is frequently neglected to a greater or less extent. For instance, new rails carelessly laid on old ties may be given a wavy surface or permanent set, due to careless handling or to uneven bearing surfaces, which cannot afterwards be remedied and will materially reduce the beneficial results intended to be obtained by the new rails. With an ordinary good track, on which light rails are replaced by heavier rails, the work of maintenance and renewals should be very much reduced, owing to the increased weight and stiffness of the rails, which reduces the deflections, so that the joints can be kept in better condition. The number of ties should not be reduced for heavier rails, as the rail should not be independently considered as a bridge or girder resting upon piers. A fairly large number of ties and fastenings greatly facilitates the maintenance and adjustment of surface, line and gauge to ensure an easy riding track, more so than when the supports and fastenings are 33 to 36 inches apart, as with English track."

TESTING STEEL.

Mr. E. F. Kenney, Engineer of Tests, Pennsylvania Railroad, said in a lecture which he delivered before the Transportation class, in the Institute of the Pennsylvania Railroad Department, Y. M. C. A., at Philadelphia:

All material used in the construction of a railroad and its equipment must be subjected to tests of some kind, but the field is such a large one that I will confine my remarks to the one material that composes the greater part of our construction work to-day. For railroad uses particularly, steel stands pre-eminent, and a thorough testing of its qualities before putting it in service is more necessary than in the case of almost any other material used.

To make the subject of tests a little clearer and possibly a little more interesting, I will first briefly sketch the operation of steel-making.

Steel is essentially a combination of iron and carbon; so is cast iron and also wrought iron. The difference is only in the amount of carbon and method of manufacture. Wrought iron is the nearest approach to pure iron—in fact, it is made as near to pure iron as the commercial methods will permit. Steel contains more carbon, to make it harder and stronger than iron would be, varying for different purposes from 0.10 to about one per cent, the strength and hardness increasing with the amount of carbon. Cast iron or pig iron, which is the crude form just as it comes from the blast furnace, is iron with about four per cent of carbon. All steel and iron contain other

elements, as phosphorus, silicon, sulphur, manganese, etc., which are incidental and not essential. The only one which particularly concerns us in the testing of steel is phosphorus. This is an evil with no redeeming features. Its effect is to make steel brittle, particularly when subjected to sudden shock, and its elimination has been the great problem of the steel-maker for years.

PROCESS OF MAKING.

The old method of making steel was to take wrought iron which had previously been made from pig iron by burning out the carbon in a puddling furnace, and recarbonizing it by heating it in the presence of charcoal. This was a slow and expensive process, and the use of steel was much limited. It was not until recent years that any direct method of making steel from pig iron was known. The first successful solution was the invention of the Bessemer process. This consists in burning out the carbon from molten pig iron by forcing a current of air through it. It is quick and cheap, and while the product is not nearly as high in grade as that made by the old process, its cheapness gave a tremendous impetus to the use of steel. The vital weakness of the Bessemer process as carried on in this country is the inability to remove any of the phosphorus. All of the phosphorus which is contained in the original pig iron remains in the steel. In the last twenty or thirty years there has been developed another and better process for making steel direct. This is called the basic open-hearth process, which burns out the carbon from a bath of molten pig iron and at the same time permits of removing nearly all the contained phosphorus. The last feature is of such tremendous im-

portance that the process has practically superseded the Bessemer process for the manufacture of steel which is to be subjected to shock. No one would think of using Bessemer steel in the construction of bridges, locomotives or car axles, or anything which has severe service to perform.

When the requisite amount of carbon is burned out of the steel, it is poured into wrought-iron molds containing two tons or more, and after cooling sufficiently is stripped of the mold, leaving the metal in the form of large ingots.

ROLLING.

The ingot is sent to the rolling-mill and forced through rolls very much on the principle of a clothes-wringer. It is drawn through successive passes, each smaller than the previous one, until the short, heavy ingot is reduced in section and drawn out into a bar sixty or ninety feet long.

It is just as necessary that this should be carefully done as the steel-making. The best of steel can be ruined if it is rolled at an improper temperature.

Steel, instead of being a homogeneous material, is in reality a mass of crystals cemented together; in fact, very similar to sandstone. The crystals are very hard, being composed of a mixture of carbon and iron, while the matrix, or cementing material, is pure iron.

This structure is not visible to the eye, but under the microscope it gives us the best test of the heat treatment of steel. To show it we have to grind the steel to a mirror polish, first with emery paper of different grades, gradually working from coarse to very fine, and finish with chamois and rouge. The slightest scratch will vitiate

the work. It is then treated with nitric acid, which etches the pure iron matrix, but does not attack the compound of iron and carbon which forms the crystals. After the etching has been carried far enough the crystalline structure is plainly visible under a magnification of about fifty diameters.

These microscopic tests are responsible for the only improvement in rolling steel which we have had for years. They are of very recent development, and have thrown light on many points which were formerly mysteries. Many instances of bad behavior of steel which were ascribed to bad chemistry or careless blowing have been shown to be entirely due to improper heating of the steel in the rolling mill. * * * * * * *

Now, the finer this structure is—that is, the smaller the crystals—the greater is the strength of the steel, and this fineness of the structure is regulated by the temperature at which the last work is done on the steel. A piece of steel which is finished at a high temperature will show a coarse grain, but steel which is worked until it gets down to a dull cherry red will have a fine, close structure.

You can see from this that it is expedient to have steel finished as cold as practicable, but finishing cold means very much more wear on the machinery of the rolling-mill and a decreased amount of production. There is a strong temptation for the maker to finish steel at high temperature, and the great records of output are only achieved at the expense of quality of the finished steel. In making steel into shapes which are thin, there is little difficulty from this source, but in heavy sections of eye-bars for bridges or in steel rails the inspector has to keep prodding the rolling-mill to secure a proper finishing temperature.

TESTS.

Surface Inspection.—When steel is being rolled it may be torn by the great strain put on it by the rolls, and flaws develop, some slight, some so deep as to hurt the strength of the bar. Sometimes cinder or slag is rolled into the steel, making a pocket, which decreases the strength. To see that no material is accepted which is defective in this way, the inspector looks very carefully over the surface. A piece is then cut from the finished bar and subjected to physical tests.

Physical Tests.—The tests usually made are as follows: Determination of tensile strength, elastic limit, amount of stretch in a given length, amount of reduction of area of material before it breaks, and freedom from brittleness, as shown by bending flat without heat a piece of the material to see whether it shows any disposition to crack.

The ultimate strength is found by pulling a piece of the material, generally not less than one-half square inch, until it breaks. This is done on a machine.

The test piece is held by two sets of jaws which are gradually drawn apart until the piece is broken. There is a scale beam like the beam of ordinary platform scales, and on this a weight is moved until it balances the pull of the machine. In some machines the moving of this weight is automatic, being governed by the making and breaking of an electric current at the end of the beam. When the pull of the machine is greater than the weight the beam goes up and, touching, completes the circuit. This starts a motor which moves the weight out along the scale beam until it forces the beam down. The current is then broken and the motor stops, leaving the

weight stationary until the increase in the amount of pull in the machine forces the arm up again. In this way the machine shows at all times the amount of tension which is on the test piece, and the inspector can watch the behavior of the test piece under the successive amounts of stress. The amount of pull shown by the machine at the moment the piece is broken shows the ultimate strength.

All materials are more or less elastic, some more so than others. A piece of steel is not as elastic as a piece of India rubber, but nevertheless it is elastic, and when you pull it it will stretch. When you release it, it will return to its original length. This is true of steel up to a certain point, which is called the elastic limit. If more stress is put on it beyond that point it stretches much faster than it did before, and when the pull is released the piece of steel will not return to its original length, but will be longer. In service we must be sure that our material is not subjected to a force which can deform it, so it is very important that this limit of the elasticity of our material should be known.

In addition to strength, our steel must be ductile. Safety demands that we should have ample warning when any material is overloaded. We want to be certain that it will stretch and bend before it breaks, so we require our test pieces to show a high amount of elongation before they break, and also ability to withstand pretty severe distortion. This is ascertained by bending the material cold, which test it must stand without showing any cracks.

On some things, such as axles, rails and eyebars for bridges, in addition to these tests of small pieces, full-sized tests are made. A complete axle is placed on supports and a weight dropped on it to test its freedom from

brittleness. It must stand a given number of blows before breaking. A section of rail is treated in the same way, except that the rail is required to stand only one blow, but that is very severe. The success or failure of the one axle or rail determines the acceptance or rejection of the lot from which the test was picked.

All material which goes into work has to pass these tests, and inspectors are sent to the different mills to see that they are carried out.

Chemical Tests.—In addition, chemical analyses are made to supplement the physical tests. This is necessary mainly because of phosphorus. Steel containing phosphorus may be very brittle when subjected to a shock such as it might easily get in service, and yet stand very well the physical tests in the testing machine, because the load is gradually applied in the machine and there is no sudden shock.

One-tenth of one per cent. of phosphorus seems like a small amount, and yet it is enough to make a piece of steel, which is otherwise first-class, unfit for use in a bridge or axle. For this reason the chemical analysis is very necessary, as there is nothing in the appearance of the steel to indicate the brittleness.

After we are certain that the material for our bridge is all right we have to have inspectors look after its fabrication in the shop. Every rivet you see in a bridge has to be tested to see that it is right. Every dimension has to be measured to insure the bridge going together properly in the field, and then the work of erection in the field has to be inspected.

While all these safeguards are necessary and are never waived, the practice of steel construction for bridges and

buildings has arrived at a point where it is quite satisfactory and gives very little anxiety.

In another field of inspection this condition is far from being realized. The practice in steel rail making is far behind that of structural steel. Rails wear out very quickly, and broken rails occur at alarming rate. If we have the rails made hard enough to withstand the traffic of the constantly increasing tonnage, we would get a crop of broken rails which would frighten every one, so we have been trying to work along "between the devil and the deep sea," making the rails as hard as we dared without running too heavily into danger of breaking. The trouble is that steel for rails is made almost universally by the acid Bessemer process. This process, as I said before, has been abandoned for bridge steel because of the treacherous character of the product, and yet steel rails, which are subjected to greater stresses and more severe treatment than any part of a bridge, continue to be made of Bessemer steel.

The severity of service on rails has increased greatly in the last ten years. The weights of locomotives and cars have increased about fifty per cent, and the speed has increased nearly in proportion. To withstand these increased stresses we have practically done nothing for the rail. Our heaviest section of rail weighs 100 pounds to the yard, and this has not been increased in thirteen years. We have made a slight improvement in rolling the rails a little colder, but other than that we have done nothing. That much can be done has been shown in tests of special rails. First we tried rails made exactly as the ordinary rails, except that we added three and one-fourth per cent of nickel, but they were not very successful, particularly as the addition of the nickel raised

the price of rails about twenty-five dollars a ton. We have since been trying rails made by the open-hearth process, and in some of these we put nickel, while in others we relied on carbon alone to give the steel the necessary wearing qualities.

We had a few rails made with a certain amount of carbon in them, and tested them for brittleness by dropping a weight on them. If they were not brittle we would make a few more with an increased amount of carbon, until we had rails of 0.90 carbon. They were very hard, but in spite of the hardness they were quite tough. This was because we were able to keep the phosphorus very low.

These rails were placed in track in competition with some ordinary rails at Union Furnace, on the Middle Division. There is a sharp curve here where trains run at high speed, and the east-bound track has to accommodate both passenger and freight traffic. This is the most severe test of rail that we can have.

The outer rail of all curves is raised higher than the inner rail, and the amount of elevation is proportional to the speed of the train. Now, on this curve at Union Furnace we have to make the elevation of the outer rail to suit the speed of the passenger trains, and when freight trains, which move more slowly, come along, the elevation of the outer rail is too great for their speed. This gives an excess of load on the low rail, and causes a mashing of the head.

Previous to the trial of these high carbon rails we had not been able to get rails which would stand this service in the low rail. The nickel steel rails which were made by the Bessemer process a few years ago wore quite well in the high rail, where they were subjected mainly to

abrasion, but they went to pieces very quickly in the low rail. * * * * * * * *

The open hearth rails have been in track fourteen months, and the ordinary rails are laid right next to them, so that they have been subject to exactly the same conditions, except that the ordinary rails have had two months' less service. The test as originally projected was to determine the relative wear of different grades of open-hearth rails, and these rails had been in track about two months when we decided to lay some ordinary rails with them for comparison. We had no doubt that the open-hearth rails would wear better than the Bessemer, but no one supposed there would be such a difference as has been shown. In spite of the extra two months of service the high carbon open-hearth rails show not more than twenty-five per cent of the wear of the Bessemer rails. In the low rail, where we have always had trouble before, the wear is so slight as to make it difficult to show on a diagram, and there is no mashing down. With all the hardness thus shown the rails are not at all brittle. A wreck occurred at this point, and though some of the rails were bent, none were broken.

The rails have proven themselves ideal, but unfortunately we cannot get them in any great quantity, for none of the mills have the facilities for making them, and it will be years before they will have such facilities. This is extremely regrettable, as they will not be expensive; if they could be furnished at all, they would cost little, if any, more than the ordinary rails, while they would last at least two or three times as long and yet be safer. The necessity for betterment has been so strongly urged to the rail-makers, and the remedy so plainly pointed out, that we have hopes that they will make a start toward

preparing themselves for the manufacture of rails of open-hearth steel. Then we expect the steel in rails to be as satisfactory as it now is for other purposes.

The questions and answers which follow were brought out in the discussion which ensued at the conclusion of the lecture.

DISCUSSION ON TESTS.

Q. Who determines when a rail is worn out?

A. The Supervisor.

Q. Is it necessary to straighten rails after they are rolled in the mill?

A. Yes.

Q. How are rails bent for curves?

A. For all ordinary curves the rails are not bent before being laid. There is sufficient elasticity in the rail to permit it being lined up to the desired curve after being spiked. For sharp curves it is bent by an arrangement called a rail bender, which is part of a track gang's equipment.

Q. Are open-hearth rails made up North, or only in Alabama?

A. In large quantities only at Ensley.

Q. Will you explain the open-hearth process?

A. The open-hearth process consists in removing part of the carbon and other impurities from pig iron by subjecting it to the action of heat and an active slag, of the proper chemical composition, in a regenerative furnace. A regenerative furnace is one in which the fuel gas and air are heated previous to ignition by heat from previously burned fuel. This is done by having the gases resulting from the combustion passing through chambers filled with

loosely laid brick, which are thereby heated to a yellow heat. The direction of the draft is then reversed, and the gas and air which comprise the fuel are brought through these heated chambers. The combustion of this preheated fuel gives the intense temperature necessary to melt the steel.

Q. Is the open-hearth rail used on railroads in England?

A. I think the London & Northwestern is the only road which does.

Q. What is the difference in cost of production?

A. Not more than a dollar or two per ton.

Q. If one rail does not stand test, is the whole lot thrown out?

A. If one rail breaks under the drop test another is tried. If that also breaks all rails from that heat of steel are rejected. If the second rail stands the test a third rail is tried, and if it fails the heat is rejected; if it stands the heat is accepted.

Q. What is done with rejected rails?

A. Sometimes they are broken up and rolled into rails of smaller section; sometimes they are remelted.

Q. Is electricity used in smelting steel?

A. No.

Q. Does crystallization of steel show a defect in manufacture?

A. All steel has a crystalline structure.

Q. Does open-hearth process require more labor than Bessemer?

A. Yes, but this cost is counteracted by the fact that less iron is lost in the open-hearth process.

Q. Of what is the bottom of an open-hearth furnace made?

A. In acid process, silica brick; in basic, dolomite or magnesite.

Q. Is a furnace shut out of commission after each heating?

A. No.

Q. How do they know when a furnace bottom is worn out?

A. By looking at it when it is empty.

Q. What fuel is used in the open-hearth process?

A. Gas, made in a gas producer.

Q. Is electrolysis the same as crystallization?

A. No.

Q. Are railroad spikes tested?

A. Yes.

Q. What is the elastic limit of bridge steel?

A. About 40,000 pounds per square inch.

Q. Where are chemical analyses of steel made?

A. At the mills.

Q. What determines the weight of rails to be put down—80, 90 and 100 pounds?

A. The character and amount of traffic.

RAIL JOINTS.

The best method of fastening the rails together is not yet settled. There are a number of different methods in use. With the constantly increasing weight of engines and heavier trains, the method of connecting the rails is becoming a vital question.

A writer on this subject says: "Two functions are performed by rail joints. One is that of resisting the rapid blows from the wheels of engines and cars of fast passenger trains, the other, the hard slow blows from heavy freight trains.

"The weight on the driving wheels of the new passenger locomotive of the high speed type is less than the new style of locomotives for freight. The latest style of freight locomotives have a weight on each driver of

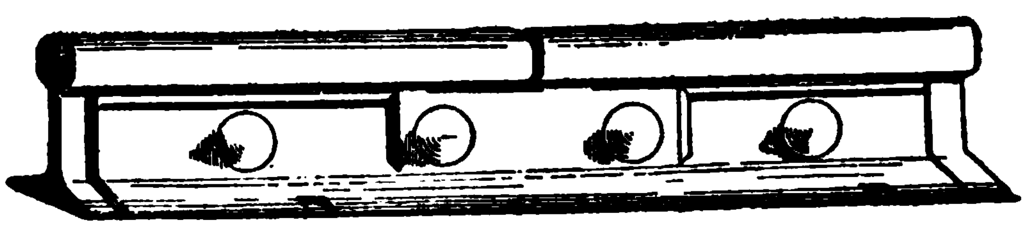


Fig. 44. Reinforced Rail Joint.

24,000 pounds, while some high speed passenger locomotives have a weight on each driver of 22,000 pounds. A 60,000 pound capacity car fully loaded will have from 11,000 to 12,000 pounds weight per wheel. In the case of a tonnage train consisting of a 12-wheel engine and 100 loaded cars passing over a rail joint, there will be four blows of 24,000 pounds made by the engine and 260 blows of from 11,000 to 12,000 pounds made by the wheels of the freight cars. When this is considered the importance of a good rail joint becomes apparent.

Section Side View.

WEBER RAIL JOINT.

Section Side View.

"COMMON SENSE" RAIL JOINT.

TRUSS RAIL JOINT

Fig. 45.

Number of fastenings required to the ton of rails.

Weight of Rail per yard.	24-foot Rail.	25-foot Rail.	26-foot Rail.	27-foot Rail.	28-foot Rail.	30-foot Rail.	33-foot Rail.
Pounds.	Joints.	Joints.	Joints.	Joints.	Joints.	Joints.	Joints.
12	23.33	22.40	21.53	20.74	20.00	18.66	16.96
16	17.50	16.80	16.15	15.55	15.00	14.00	12.72
20	14.00	13.55	12.92	12.44	12.00	11.20	10.18
25	11.20	10.74	10.32	9.95	9.68	8.96	8.14
30	9.83	8.94	8.60	8.29	8.00	7.46	6.78
35	8.00	7.68	7.38	7.11	6.86	6.40	5.81
40	7.00	6.71	6.45	6.22	5.99	5.60	5.09
45	6.22	5.96	5.74	5.52	5.33	4.97	4.52
50	5.60	5.37	5.16	4.97	4.79	4.48	4.07
55	5.09	4.88	4.69	4.52	4.36	4.07	3.70
56	5.00	4.79	4.61	4.44	4.28	4.00	3.63
60	4.66	4.47	4.30	4.14	4.00	3.73	3.39
62	4.51	4.33	4.16	4.01	3.86	3.61	3.28
64	4.37	4.19	4.03	3.88	3.74	3.50	3.17
65	4.30	4.13	3.97	3.82	3.69	3.44	3.13
67	4.17	4.00	3.85	3.71	3.58	3.34	3.03
70	....	....	....	....	....	3.20	2.90
75	....	....	....	....	....	2.98	2.71
80	....	....	....	....	....	2.80	2.54
85	....	....	....	....	....	2.63	2.39
90	....	....	....	....	....	2.48	2.26
95	....	....	....	....	....	2.35	2.14
100	....	....	....	....	....	2.24	2.03

Fig. 46.

"The length of rail joints varies from 48 inches with six bolts to 24 inches with four bolts. The spacing of the ties under the rail joints is not uniform; some roads place the joint between the ties, others place a tie directly under the joint; theoretically the former will permit the rail to respond to the wave action more fully than the latter, and those advocating the first style of spacing the ties claim it makes an easier riding track on account of the wave motion of the rail not being so greatly interfered with."

The practice on tangents is to use "even joints," that is, joints directly opposite each other, and on curves "broken joints," that is, the end or joint of one rail in a track is laid opposite the center of the other rail.

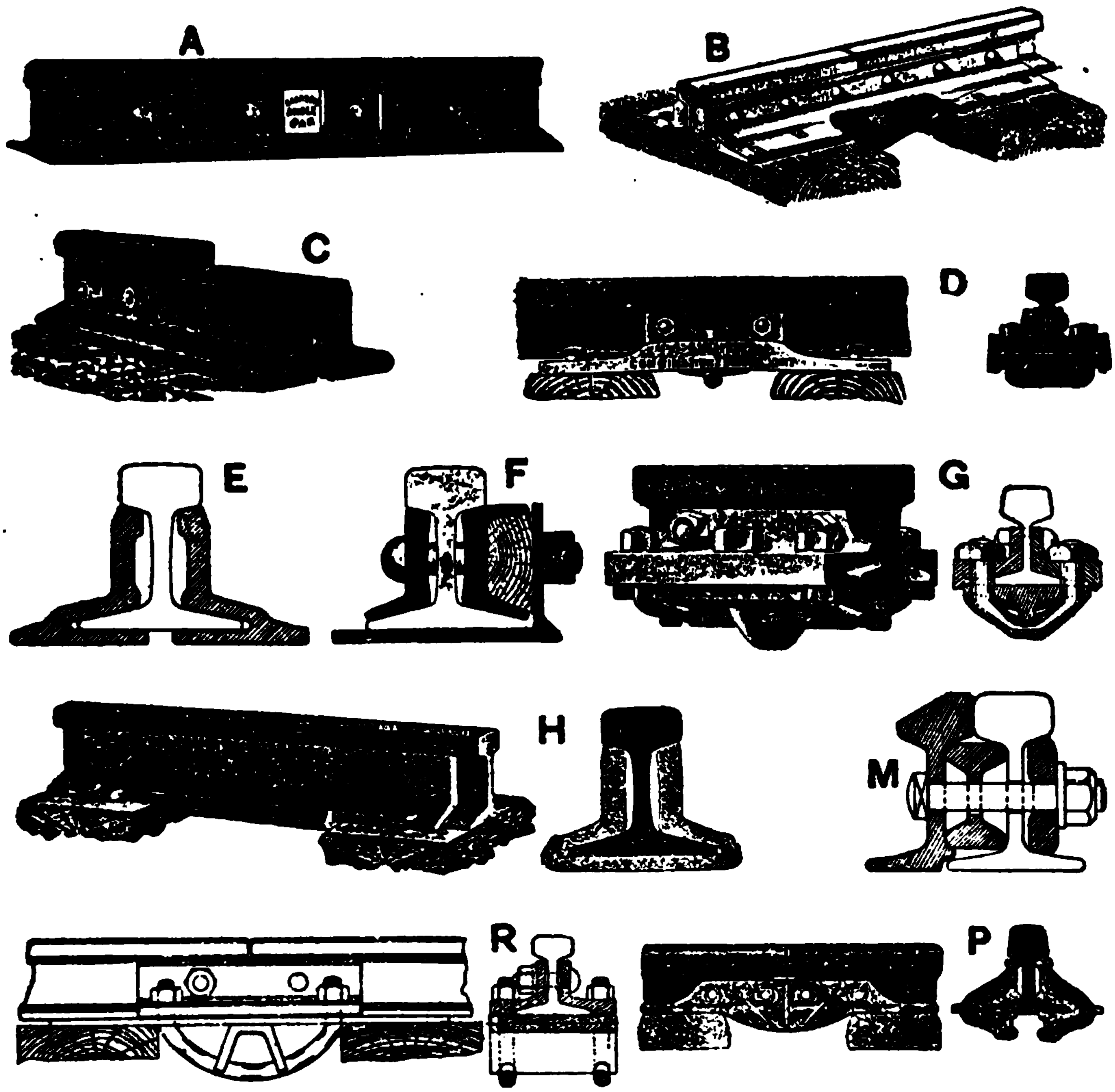


Fig. 47. RAIL JOINTS OR SPLICES.
A, Sampson Angle Bar; B, Bonzano Splice; C, Continuous Splice (old pattern); D, Fisher "Bridge" Splice; E, Continuous Splice; F, Weber Splice; G, Fisher "Triple Fish" Splice; H, Permanent Splice; M, Barschall Splice; P, Price Splice; R. Long Splice.

There are two general types of rail joints; the "suspended" and the "supported." The suspended is where the ends of the rails come between two ties, the supported is where the ends of the rails meet directly over a tie.

When the rails are "even jointed" (or, as sometimes called, "square jointed"), the supported joint is most generally the practice, but when the rails are "broken jointed" the suspended joint is the common practice. Those not familiar with track maintenance ordinarily favor the supported or rigid joint. One having had a little practical experience in track work readily perceives the advantage of a suspended rail joint for general purposes. Mr. A. C. Caldwell thus refers to this subject: "In passing over the rails, at a high rate of speed, the wheels, especially those of the locomotive, have a hammer-like blow effect on the joints. If the joint is stiffer than the rest of the rail, there is generally a jolt and a consequent damage to equipment. The supported joint being unable to yield under the heavy blows will not, as a rule, hold up to the rest of the track and is soon pounded into the ballast. With the suspended joints, there is a slight give which relieves too great a strain on the joint when the train is passing over. Again, the blow is distributed more evenly.

"The joint bars used for the joining of the rails are of many kinds. They may be classified into two general types: The "Fish" (inventor) plate, which is a metal plate fitting close to the web of the rail and of a depth equal to the distance between the ball or head of the rail and the flange or bottom. The angle bar being somewhat similar except that more metal is added and sufficient to carry over the top of the flange of the rail and almost touching the tie. The continuous joint is one where more metal is added so that the joint plates reach clear around the flange of the rail, the two plates just meeting at the half-way point under the bottom of the rail. Some of the joints now on the markets have a base

plate in addition to the continuous plates just described for holding the rail to the ties. The spikes most commonly used are about 5½ inches long and from one-half to nine-sixteenths inches through. The spike head projects on one side so as to gain a good purchase of the rail and is wedge shaped in the shank. Other spikes

FIG. 1. CAST STEEL STEP FISHPLATE

FIG. 2. CAST STEEL RAIL JUNCTION

FIG. 3. FORGED STEEL STEP FISHPLATE

Fig. 48. Compromise Splicing Arrangements.

such as the Goldie, whose driving end is pointed, the Greer, with its extra head for easy spike pulling, the screw spike, with its firm clutch of the tie, are also used. The first mentioned is, of course, more common through its cheapness and simplicity. There is also another spike called the boat spike used for work in road crossings with big heavy planks."

Joint ties should be tamped first and the other afterwards, bringing the rail to grade with the joint. The ties at crossings, switches and frogs should be tamped very thoroughly.

Low joints will be a frequent trouble in track on a new road and the uneven settlements of the embankments will require a great deal of extra labor and watchfulness on the part of the section force.

Creeping Rails.—The "creeping" of rails is a source of trouble in maintenance of track. It is more noticeable at switches than at any other points, but is less troublesome where the split switch is used than at stub switches. The Roadmasters' Association after considerable discussion of the subject arrived at conclusions as follows:

"The creeping is not alike for both rails; in double track roads the rails creep in the direction of the traffic; the movement is greater on down than up grades and is worse where tracks have to be laid over marsh or soft yielding sub-soil. On single track it is most noticeable on down grades, and where there are descending grades from both directions, the rails creep down and come together in the valley. On curves, the outer or high rail creeps the more and where there are successive reverse curves, especially on grades, the creep starts on tangents at the approach and continues on the high rail to end of first curve, then the opposite rail on the reverse curve shows the more creep. In other words the high rail in each successive curve is found to creep more than the low rail. The cause of creeping is because of a rolling load passing over the rail which depresses the track directly under it and produces a corresponding elevation and depression ahead and behind it which may be likened to a wave motion. Mr. F. A. Delano, President, Wabash

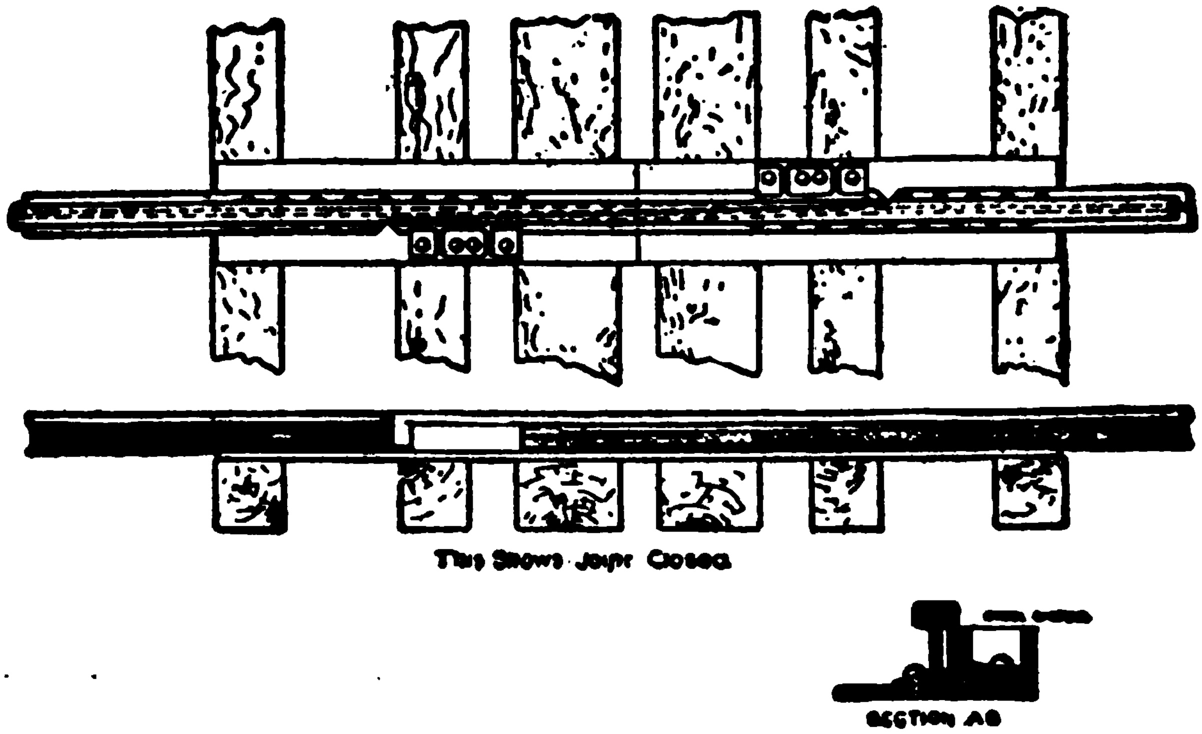
Railroad, while superintendent of freight terminals of the Chicago, Burlington and Quincy R. R., assisted by Mr. J. E. Howard of the Watertown Arsenal, found by experiment that the ground near a locomotive weighing 110,000 pounds on a track having 66 pound rails resting on oak ties, 17 to a 30 foot rail, and in gravel ballast, the greatest depression was 0.161 inch under the middle driver. Under similar conditions, but with cinder ballast instead of gravel, the depression under the middle driver was 0.230 inch. The depression of the ground caused by a 125,000 pound locomotive under the above conditions with gravel ballast at a point opposite the main driver was as follows:

"Distance from the rail, 31 inches; depression 0.047 inch.

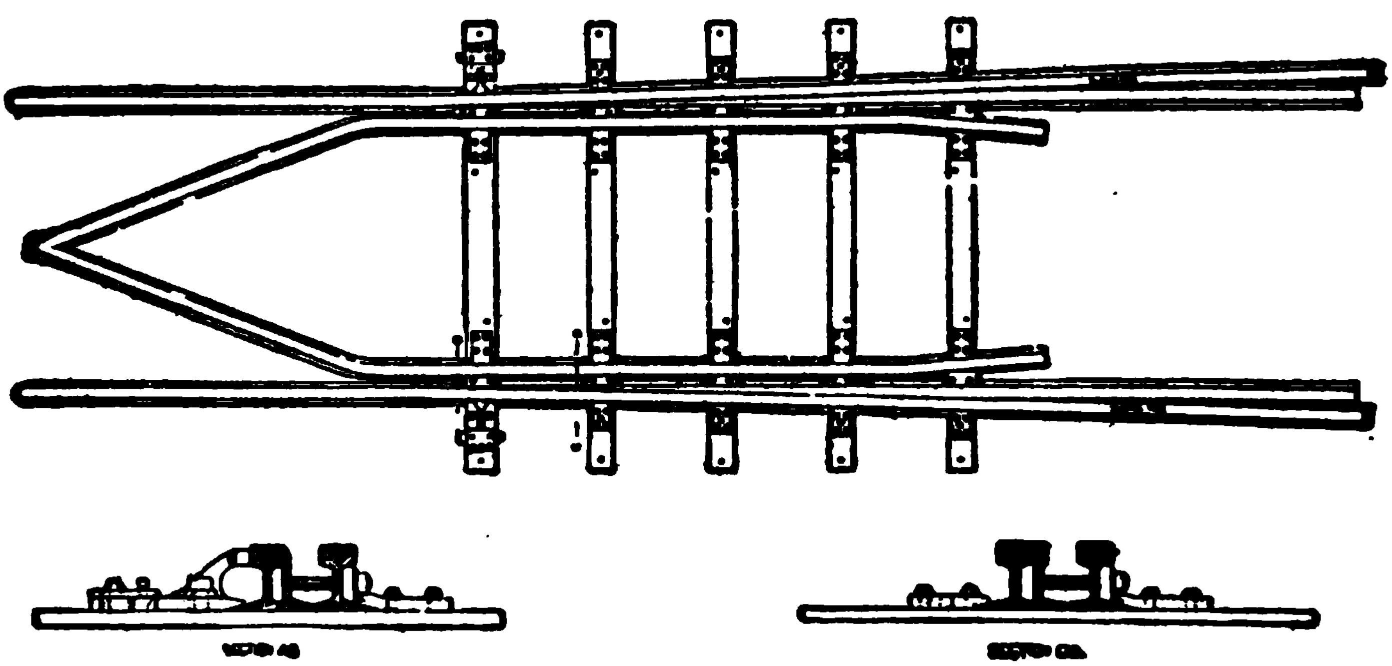
"Distance from the rail, 61 inches; depression, 0.013 inch.

"Distance from the rail, 91 inches; depression, 0.001 inch.

"With the track depressed under the weight of an engine a corresponding rise just ahead of it to be afterwards depressed as the engine approaches it and passes over it produces a violent wave motion under high speed which is the cause of creeping rails. The movement of the rail tends to carry the tie with it and where the ballast is not filled up to the top of the tie at the end, the tie acts as a lever, the balance at the center being a fulcrum and the twisting of the tie in the track tends to tighten the gauge; this takes place more at the joint ties and more particularly where the rails are laid with broken joints. This tendency to move the ties takes them off



PLAN AND ELEVATION OF A JOINT TO TAKE UP THE EXPANSION AND CONTRACTION OF RAILS.



EXPANSION JOINT FOR A BRIDGE OR DIFFICULT PIECE OF TRACK.

Fig. 49. Used on bridges and at points where expansion and contraction of rails is such that they cannot, without considerable trouble, be kept in line. This device is also used where creeping of rails is troublesome.

their well tamped bed and tends to produce a creeping of the whole track which will lead to a general disintegration and destroy the alignment and surface, which will require a large amount of hard work to place the track in proper condition again. There is not at present any known method of preventing rails from creeping, but the evil can be lessened by resorting to devices for anchoring the rails at the joint by spiking the tie through the slot in the angle bar; the larger the number of ties thus spiked, the more firmly the rail is secured. Some roads having rails laid with broken joints use sections of an angle bar, bolted to the rail opposite the joint, and spike the tie through the slot in these sections of the angle bar; this tends to prevent the tie from twisting and tightening the gauge. One end of a flat bar of iron turned half round is sometimes placed inside the nut of track bolts at the joint, and the other end spiked to a tie to secure greater resistance. At entrances to yards or points where the rails creep much, some roadmasters anchor the rails by spiking a piece of strap iron to three or more ties, the spikes being placed in the holes bored in the strap iron. The vertical and lateral motions can be retarded or reduced to a minimum by having a stiff rail in section to transmit the load over the greatest possible surface of ties and ballast with good broad ties placed as close together as good tamping will permit, the spikes should be well driven and the ballast dressed off as full as possible at the end of the ties. Figure 49 represents plans sometimes adopted to allow for the expansion and contraction at difficult points."

One authority states that: "A steel rail 30 feet long expands ¼ of an inch for a change of 100 degrees in

temperature. Some roads, upon laying rails, allow the following expansion:

"At zero expansion should be ¼ inch.
"At 25 above expansion should be 3-16.
"At 50 above expansion should be ⅛.
"At 75 above expansion should be 1-16.
"At 100 above expansion should be 0.

"Note.—Expansion should always be uniform. By observing this and using care in placing plates and in spiking, much can be done to stop 'creeping track.'"

Table compiled by Mr. W. C. Downing showing amount of expansion of steel rails and thickness of shim required for a 30-foot rail:

Temperature Degree Fahrenheit.	VARIATIONS.		Thickness of Expansion Shim in Inches.
	In Decimals of an Inch.	In Fractions of an Inch.	
— 30	.3744	24-64	6-16
— 20	.3510	23-64	6-16
— 10	.3276	21-64	6-16
0	.3042	19-64	5-16
10	.2808	18-64	5-16
20	.2574	16-64	4-16
30	.2340	15-64	4-16
40	.2100	14-64	4-16
50	.1872	12-64	3-16
60	.1638	10-64	3-16
70	.1404	9-64	3-16
80	.1170	7-64	2-16
90	.0936	6-64	2-16
100	.0702	5-64	1-16
110	.0468	3-64	1-16
120	.0234	1-64	1-16
130	.0000	....	....

The rails are supposed to be in contact at a temperature of 130 degrees Fahrenheit.

The following rule is enforced on the Northern Pacific Ry., concerning expansion:

"Proper allowance must be made for expansion, according to temperature, as follows:

Temp.	Ins.	Temp.	Ins.
100°	0	40°	$\frac{3}{16}$
80°	$\frac{1}{16}$	20°	$\frac{1}{4}$
60°	$\frac{1}{8}$	0°	$\frac{5}{16}$

"Proper expansion must be secured by the use of iron shims, provided in accordance with the above specifications, except where track is laid on a steep grade, when sawed wooden shims of proper thickness will be provided. These shims must be left in place until track is full spiked, bolted and thoroughly anchored.

"In order to prevent rails from 'creeping,' it is absolutely essential that each individual rail shall be so thoroughly anchored as to insure freedom from contact with adjoining rails. Creeping can not be prevented, if a number of consecutive rails are in contact."

LINE AND SURFACE.

The Pennsylvania Ry. issues this rule for lining and surfacing: "The track shall be laid in true line and surface; the rails are to be laid and spiked after the ties have been bedded in the ballast; and on curves, the proper elevation must be given to the outer rail and carried uniformly around the curve. This elevation should be commenced from fifty (50) to three hundred (300) feet back of the point of curvature, depending on the degree of the curve and speed of trains, and increased uniformly to the latter point, where the full elevation is

attained. The same method should be adopted in leaving the curve."

The following rules are in force on the Northern Pacific Ry.: "To insure perfect alignment at rail ends, the rails should be brought squarely together, the splices placed and carefully bolted before spiking. Perfect alignment at rail ends is of great importance in order to prevent excessive flange wear.

"The position of the brand on the rail is immaterial, whether right or left, inside or outside, but its position must be uniform with the contiguous rails, and the brand should not be alternated on the same line of rails.

Rail Bender and Straightener.

Curving.—Rails in curves of over 2 degrees must be separately curved, and before being placed in track. An Emerson rail bender or bender of similar type will invariably be used for this purpose. The sledging of rails is positively prohibited.

"Particular care must be given to insure uniform

curvature of the rail throughout its length, in accordance with the following table of middle ordinates:

Degs	Ins.	Degs.	Ins.
1	$\frac{1}{4}$	11	$2\frac{9}{16}$
2	$\frac{1}{2}$	12	$2\frac{13}{16}$
3	$\frac{11}{16}$	13	$3\frac{1}{16}$
4	$\frac{15}{16}$	14	$3\frac{5}{16}$
5	$1\frac{3}{16}$	15	$3\frac{1}{2}$
6	$1\frac{7}{16}$	16	$3\frac{3}{4}$
7	$1\frac{5}{8}$	17	4
8	$1\frac{7}{8}$	18	$4\frac{1}{4}$
9	$2\frac{1}{8}$	19	$4\frac{1}{2}$
10	$2\frac{3}{8}$	20	$4\frac{9}{16}$

"Note.—Ordinate at quarters equals three-quarters of middle ordinates.

"Joints and centers should be gauged first and the track gauge must be applied at as many points as may be necessary to insure perfect and uniform gauge.

"Easement curves must be spiked to gauge at five different points within each rail length, and all track must be accurately gauged when spiked.

"Suitable track gauges for use on tangents and curves, which will insure the retention of the proper gauge during the operation of spiking must be used. All track gauges must be tested by the engineer or roadmaster at the beginning of the working season, and the date of inspection recorded."

Correcting Alignment on Curves.—In a series of circular letters to his trackmen, which subsequently were published by the Railway Review, Mr. Moses Burpee, Chief Engineer, B. & A. R. R., says:

"Railroad line is originally established with the en-

gineer's transit instrument and chain, and with these it is possible to run a line absolutely straight or with curvatures of any degree."

He then goes on to explain how imperative it is to have a first-class track for heavy traffic, and tells how advisable it is to use instruments to define the line. He emphasizes the importance of trackmen gaining a knowl-

Warren Circular-End Track Gage.

McHenry Adjustable Track Gage.

Fig. 50.

edge of the properties of curves, which they will find very useful when track details are left almost, if not wholly to them. He says he believes any man can easily learn the principles, provided he has not already done so, as explained by him. In a familiar, easy style, he proceeds to call attention to the disagreeable motion of a car when rounding a curve in which there are sharp and flat places alternately. This, he says, can be remedied by lining the curve with perfect uniformity, making

uniform elevations on the outer rail to agree with the curvature. "You can imagine," he says, "how much extra wear and tear a train suffers on badly lined curves by the swaying of the cars, twisting the frame and wrenching the couplings, and so on. Besides this, it must, no doubt, cost more in engine power to pull a

Fig. 51. Laying Track.

train over badly lined track. How much extra power is needed can not be guessed, but with proper appliances can be measured. Yet it is not necessary to know, for we can safely assume that it is cheaper to move loads on good tracks than on bad, and this is one good reason, in addition to that of the difference in wear and tear, for keeping the track in the best possible condition.

"Still another and perhaps the most important of all

in an economic sense is the fact that the speed of trains may be greatly increased on good track as compared with bad—thus enabling the transportation of larger quantities of freight and more passengers with the same number of engines and cars. By far the greatest consideration of all is that of safety, which is, of course, enhanced by all track improvement. Therefore, inasmuch as an important part of the trackman's work is to reduce the friction and expense of moving traffic over the road it is important for him to know and apply the principles necessary to good work."

Continuing, he further says: "In railroading, line is either straight or curved. Technically, straight line is called tangent, and for convenience and brevity we will use that name. Curves are commonly spoken of as flat and sharp, but for definite designation, when it is necessary to know just how flat or sharp they are, we speak of them as being of a certain number of degrees. A one degree curve changes direction one degree each 100 feet, and 2 degree curve twice as much, a three degree curve three times as much, and so on.

He then goes on to explain the rules and methods for finding deflections up to a few hundred feet, the simplest rule as given by him is this:

"Extend the tangent beyond the B. C. and mark the end of the first 100 feet from B. C. I., the end of the second 100 feet mark 2, the third 100 feet 3, and so on. Measure the side on which the curve runs, at point 1, the deflection distance, equal to 10½ inches multiplied by the degree of curve; for point 2, square 2 (that is, multiply it by itself) and the product 4, by the deflection at 1; for point 3 use its square, 9, for the multiplier, etc."

He accompanies this explanation with a sketch and

table which we reproduce. He refers to it as Table 1. This table, he says, will also give deflections for curves 1 to 8 degrees up to a certain limit, within the scope of which but a very small error is found, "but," he says, "beyond that limit the rule would not answer."

Continuing, he says, speaking of the rule as he explains it: "On account of its simplicity it is worth remembering, and can be used very often when the means of finding correct curve points are not at hand."

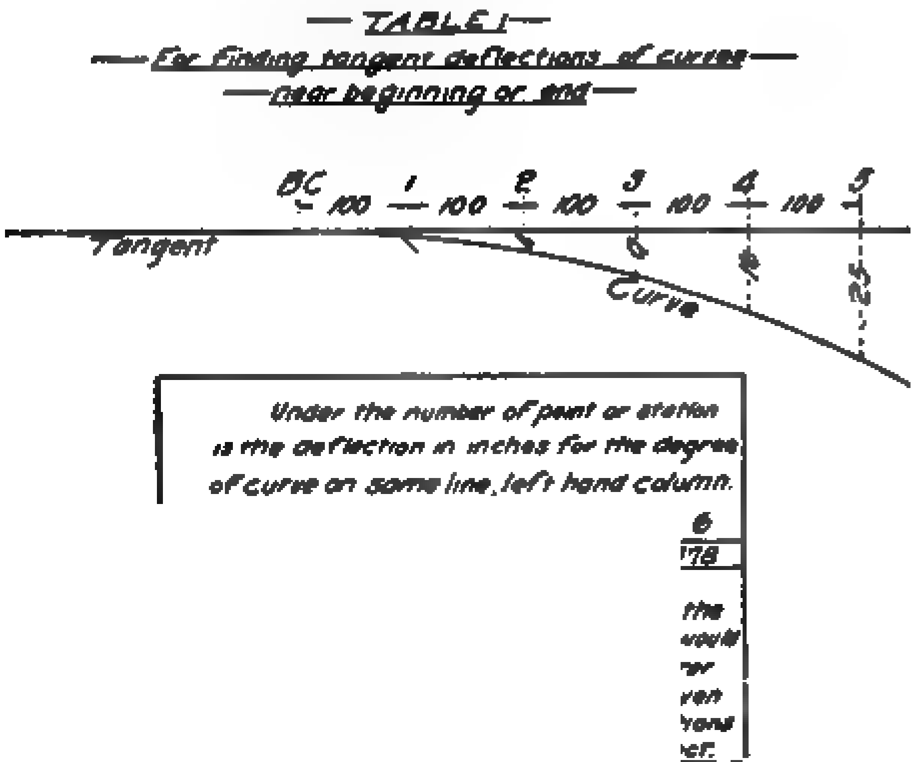


Fig. 52.

The trackman should, he says, "carry a good line all the way around a curve. No matter how well a curve may have been originally lined, there are many ways for it to get out of line each year, and the longer it is left without re-lining with transit, the worse it is apt to become."

He goes on to illustrate ways by which roadbed and track may get out of line, shows the difficulty of exactly lining to the original curve, and points out the advantage of knowing how to smooth up badly lined curves to avoid sudden changes in direction.

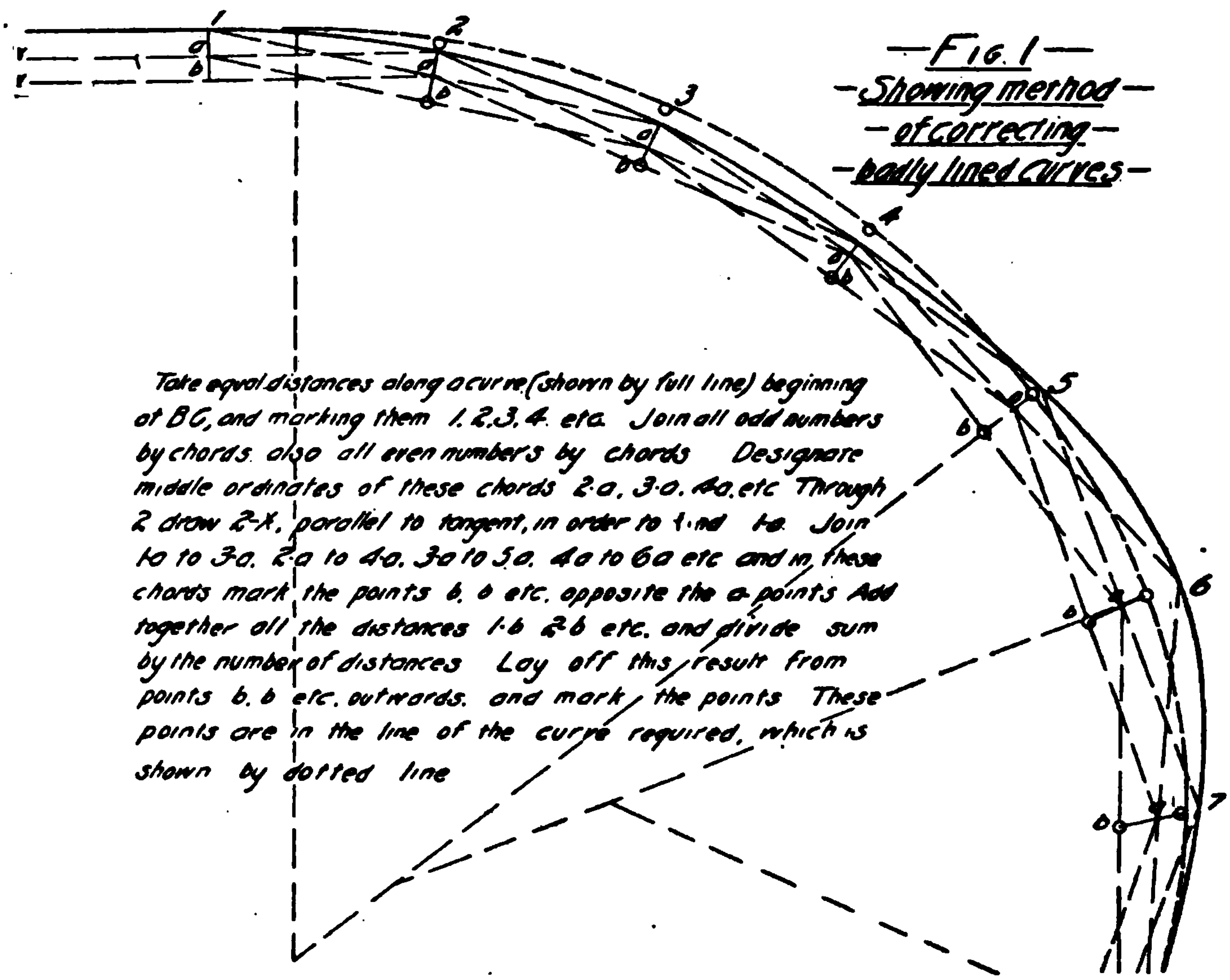


Fig. 53.

Continuing, he says: "With all due respect to instrument work, I think it not unreasonable to say that the section crew can, by the intelligent use of the following rule, do as good a job of lining with a fine cord and a pocket full of nails as an engineer can with a transit. The cord should be a few feet longer than two rail lengths and the wire nails about 6 or 7 inches long; about 15 or 20 of them should have small tags with the letter A,

the same number with the letter B, and as many more blank ones will probably be found convenient.

"Fig. 1 shows a method of correcting the line of a very badly lined curve. From point 1 to 3 it is sharper than it should be; from 3 to 5 flatter, and from 5 to 7 it is very much too sharp. For convenience it will be better to use the rail joints if the rails are all of equal lengths. If they are not, points should be measured around the curve, say 50 feet apart (in which case the cord must be 100 feet long), and the rail marked with chalk or otherwise at these points, 1, 2, 3, 4, etc., placing 1 at the beginning of the curve usually called B. C. Sight along the gauge line of rail, first from 1 to 3, and place in this line opposite 2, one of the nails marked A. Then sight 2 to 4 and place a nail opposite 3, also marked A., and so on around the curve, sighting between odd numbers for the setting points A A A opposite even numbers, and sighting lines between even numbers for setting points, A A A opposite odd numbers. These points may be designated as 1A, 2A, 3A, etc. In order, however, to find 1A, which is opposite the B. C., we need to draw a line backwards from 2 and parallel with the tangent. We may do this by sighting from 2 and finding a point outside the line exactly opposite 2, which will range with the rail along tangent, and measure the distance from the point to 2. Then lay off this distance at 1 for 1A. Then from 1A sight to 3A and in this line opposite 3A place nail marked 2B and sight from 2A to 4A, and opposite 3A set another nail marked 3B, and so on around the curve.

"Next add together all the distances, 1B, 2B, 3B, 4B, etc., between gauge line of rail and points B that will have been thus set, and divide by the number of the

distances. The B points will lie in a curve which is very nearly true, and by measuring outwards from these B points the average as above found we get the proper position for the rail, to which it should be thrown. When laying off the final points they should be marked by the blank nails; then the nails marked A and B should be removed and the new line tested in the same way that the rail was, and if the new ordinates 2A, 3A, etc., are found to be very nearly equal it may be as well to line the track to the new curve. However, it is possible, if there is still considerable inequality in the ordinates, to reduce that inequality by repeating the operation, using the line marked by the blank nails as a starting line just as you at first used the rail. It is sometimes the case that the roadbed is not in good line, and consequently it will not be possible to exactly line the track, and even one line of ordinates, viz., those designated by A will give a line as good as can be used, and that although the B line will be nearer a true circle it may move the track too much to one side of the solid roadbed.

"The figure shows how a very irregular curve is improved by only two lines of chords and ordinates. The dotted line is a true circle which very nearly, but not quite, strikes the points found. These points are the centers of the little circles. It is probable that one or two more lines would have brought it so near that the difference would have been almost imperceptible. It is not possible to draw a perfect circle in this way, but the oftener you correct what you have, the nearer the resulting curve is to perfection, and as you always have in starting a curve which is pretty near you will soon get one that is very nearly perfect and on which no defects in driving quality can be found.

"You will see in Fig. 1 that a true circle extends from between 1 and 2 to 5, but that a circle of shorter radius (the line drawn to center) is required from 5 to 6, and of one of still shorter radius from 6 to some distance beyond 7. In the original curve there is considerable bulge opposite those points, and it would require a repetition of the process to draw that bulge in to a true circle. But sometimes curves are made originally of varying rates of curvature in different portions, and to change such to uniform curvature would be wrong. Curves having one portion of different radius from another portion are called compound curves, and are frequently used in rough side-hill country. It is scarcely possible for a trackman, or others to find the exact points where the curvature changes unless the original point is marked by witness stakes. The use of the above rule will show nearly where such points are, and it will improve or make the change from flat to sharp curvature a gradual instead of an abrupt one. The point of change or compounding can be detected by the changing length of ordinates, and when located the portions of the curve on either side should be treated independently of each other.

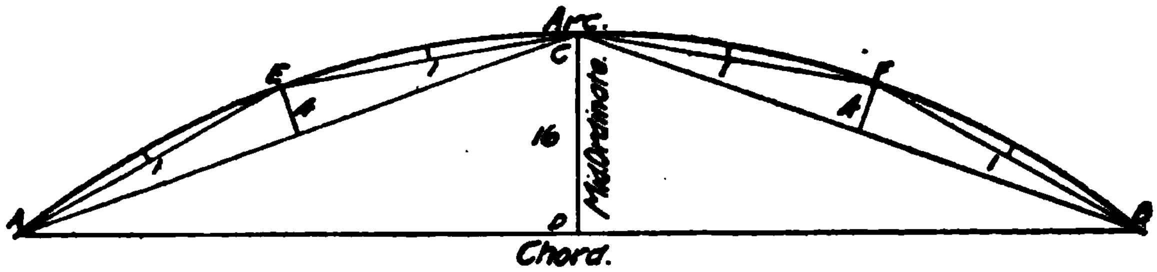
"The above statement of the rule uses the gauge line of the outer rail of curve to work by. It may be better to drive the blank nails along the center of the track as it is, finding them by the center mark on the track gauge, and correct the line in the same way as above described. This will avoid working close to the rail, which might obstruct the setting of the points if the rail instead of the center of the track were used."

Middle Ordinates.—Having shown how to ascertain whether a curve is out of line and how to correct bad line in curves, Mr. Burpee goes on to explain another

method of doing the same thing, which he says, for short curves may be a better one.

Continuing, he states: "Any distance along a curve may be taken, but, for convenience sake, the reason for which will be seen as we go along, it is better to take a distance which can be divided into eight equal parts.

TABLE 2.



The arc above represents a railroad curve 8 rails long, each of equal length, extending from A to B. Its middle ordinate is C D. Divide arc into 2 halves, A-C and C-B, and also into quarters at E and F. Middle ordinates of half-arcs are ¼ length of that of whole, those of quarterarcs are ¼ that of half-arcs. These values are marked on figure as 1, 4, 16.

TABLE OF ORDINATE LENGTHS.										
Degree of Curve	1	2	3	4	5	6	7	8	9	10
Middle Ordinate 60' Chord	1	1 7/8	2 7/8	3 3/4	4 3/4	5 5/8	6 5/8	7 1/2	8 1/2	9 3/8
" " 66' "	1 1/8	2 1/4	3 3/8	4 1/2	5 5/8	6 7/8	8	9 1/8	10 1/4	11 3/8
" " 50' "	5/8	1 3/8	2	2 5/8	3 1/4	4	4 5/8	5 1/4	5 7/8	6 1/2
" " 100' "	2 5/8	5 1/4	7 7/8	10 1/2	13 1/8	15 3/4	18 3/8	21	23 5/8	26 1/4

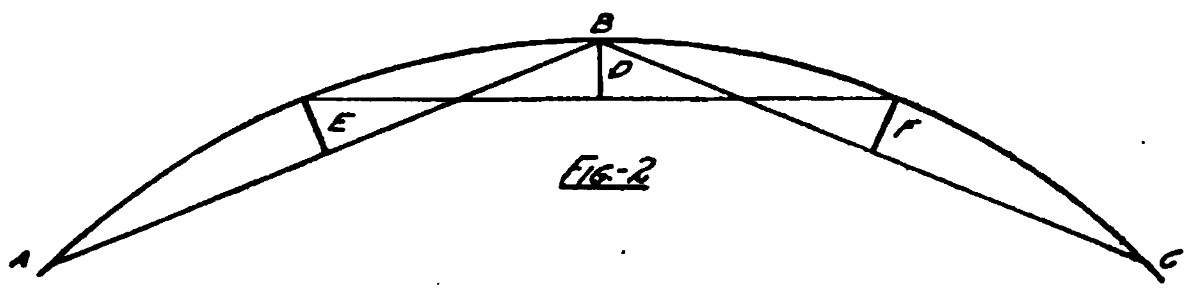
For length of ordinate, look in column under figure representing degree of curve, and in same line as length of chord given in left hand column

Note—The line for chords of 60' corresponds to two 30' rail lengths That for 66' to two 33' rails.

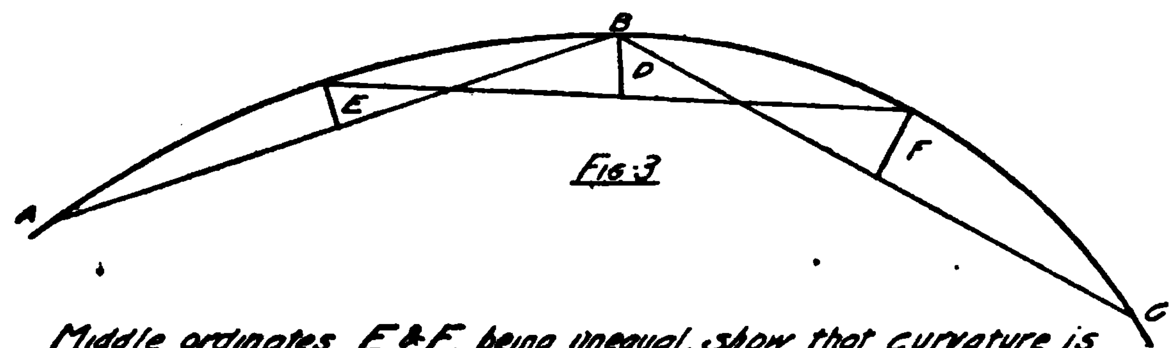
Fig. 54.

"Referring to the figure with Table 2, lay out chord AB and find D at its middle point, just opposite C, the middle of the arc. CD is the middle ordinate of arc AB. Again find chords and middle ordinates of half arcs AC-CB, and of quarter arcs AE-EC-CF and FB. The middle ordinate of the half arc is one-quarter that of

the whole arc, and the middle ordinate of the quarter arc is one-quarter that of the half arc, or one-sixteenth that of the whole arc. Therefore, in order to make the curve AB uniform, measure off the proper ordinate lengths from the chords, using a quarter of CD at E and F for ordinates of half arcs, and a sixteenth of CD as ordinates of the quarter arcs. Remember that one end of the ordinate is on the middle of the chord or straight line



Middle ordinates E, D, & F, being equal, show that curvature is equal, from A to C.



Middle ordinates E & F being unequal, show that curvature is not uniform, and for arcs AB & BC to be properly joined at B, the middle ordinate, D, must be an average of E & F.

Fig. 55.

drawn from end to end of arc; and the other end must be a point in the curve. In Table 2 chord length is in feet, and length of ordinates are given in inches.

"This method will be found convenient for portions of a curve of 8 rail lengths in any curve up to 6 degrees, which will not bring the point D off the roadbed. For sharper curves it will be better to use some shorter arc; for instance, one composed of 8 times 25 feet, the ordi-

nate of which will be about two-thirds that of the chord with eight thirties; or an arc of 8 times 20 feet, the ordinate of which will be less than half the same.

"It, however, has this limitation, namely, that you cannot be sure, when you need to repeat the lining of successive portions of a curve such as is represented in the arc AB, Table 2, that you may apply the point A to the point B; that is, begin one arc where you left off the other, and that the curve will be uniform throughout the length of the two arcs. Should your curve be not a compound but a simple one, that is, one which has an equal length of radius, or equal degree of curvature throughout, it is very unlikely that any error at the point where the two arcs join each other will amount to anything serious, but should it be perceptible, it can be lined by eye without trouble. But you can test the line if there is any doubt, after you have run in two arcs in this way. Join the middle points of the two. This gives an arc the same in every way as AB. Fig. 2 explains this, the arcs AB and BC each being equal in every way to the arc AB in Table 2, but not showing the half and quarter arcs, as they are not in this case necessary. A new arc EF is composed of one-half of each of the two arcs laid down and one end of its middle ordinate will be the point where the two join each other. If the middle ordinate is equal in length to the middle ordinate of either of the others, then the curvature is uniform for the length of the two arcs.

"If, however, we find the ordinate F of different length from E, it indicates that curve is either out of line or is 'compound.' By referring to Figure 3 we see two arcs of a compound curve, joined at the point of compounding. Both these arcs can be lined separately by the rule

with Table 2, but the middle ordinate must be of different length, and if we find that the middle ordinate D, Figure 3, of the arc made by taking a half each of AB and BC, is an average of E and F, it is proof that the curve throughout the two arcs is properly lined.

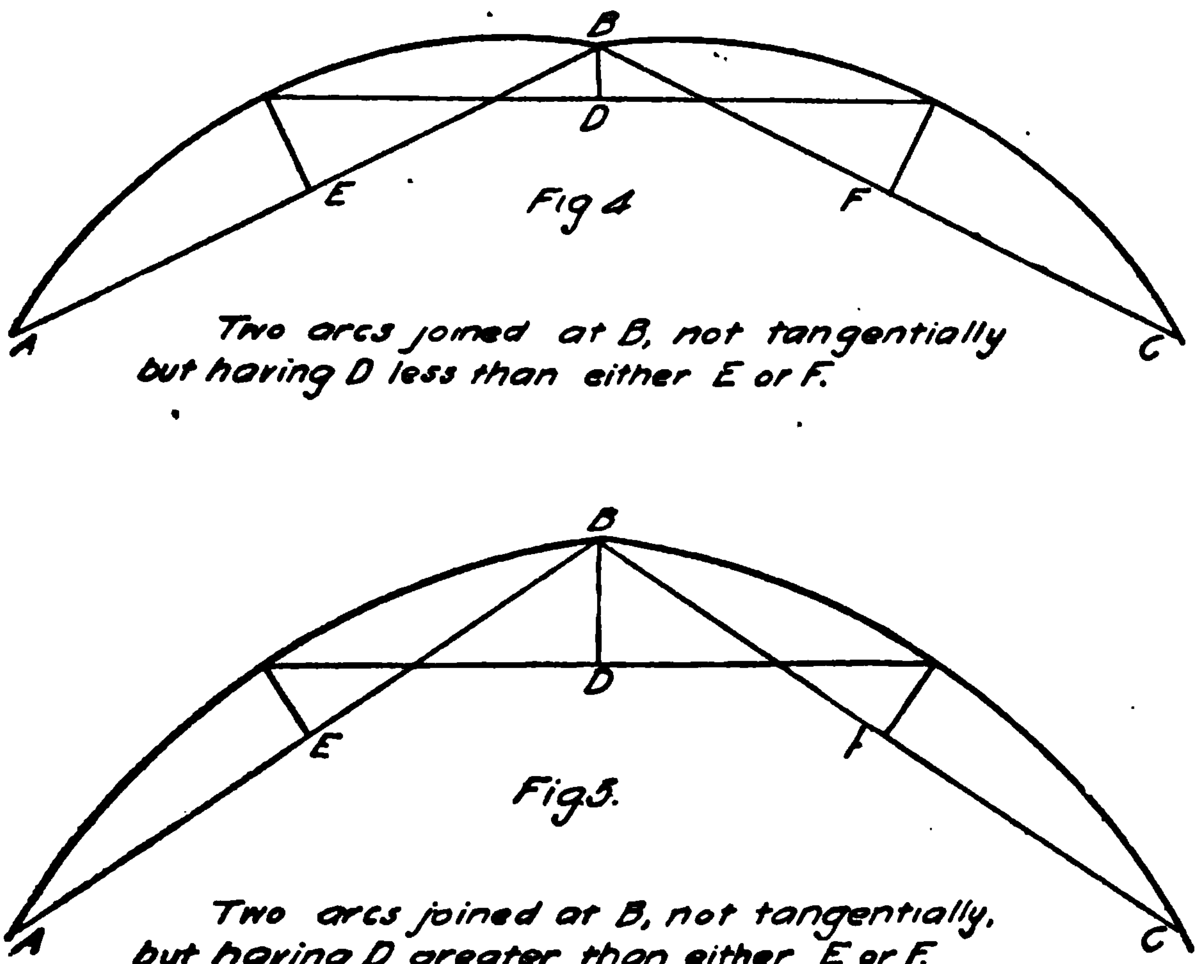


Fig. 56.

"Figure 4 shows the two arcs each in perfect line, independently of the other, but not properly joined at B, where the ordinate D is less than F or E. Figure 5 shows a case where D is greater than F or E. When D is of the proper length, as before described, the two arcs are said to be joined tangentially."

Transition Curves.— Passing on in order he next comes to what is sometimes called "tapering off the curve," and also known as easement, spiral or transition

curve. Mr. Burpee says he prefers the term transition curve when describing making a gradual change from a tangent to a curve. He says:

"The need for a transition curve lies in the fact that on all curves where trains are run at speed, it is necessary to raise the outer rail in order to give an inward inclination to the cars and prevent them from tipping outward dangerously or uncomfortably by the reason of the centrifugal force due to curve motion. Of course, this elevation of the outer rail must be made gradually, so that its tendency to raise one side of the car shall be only so fast as to be readily absorbed by the springs. The idea is to avoid the sudden and disagreeable sidewise motion which is noticeable where no transition is used.

"Most of us remember the old rule used years ago which said you should give an inch elevation per degree of curve at the B. C. and E. C., and run this elevation off on the tangents at the rate of one inch in 50 feet. For instance, the elevation for the outer rail of a one-degree curve should begin 50 feet before you get to the B. C., and gradually increase until you get the full inch just at the B. C.; this rate to be maintained around the curve to the E. C., and then taper off to level in 50 feet. To work out this plan on a 3-degree or 4-degree curve causes the cars to tip badly just before coming to the curve. Usually 3 or 4 bad vibrations occur before settling down to smooth motion.

"Several years ago, it was thought, and by many strongly argued, that transition was entirely unnecessary, and perhaps with speed of 25 miles per hour it was. It might also be left out of the question with very easy curves, say one of one degree or two degrees. The

usual practice of engineers then was to run uniform curvature from B. C. to E. C.

"In many cases, intelligent trackmen improved on this by tapering off the points of curves. Sometimes this practice was criticised by engineers, but not generally. It was admitted to be an improvement, but one which could be introduced without the engineer's help, and, in fact, there were no rules made for transition curves until recent years. There are two reasons for the growth of the idea and use of the transition curve. One, the extension of railroads into country requiring sharp curvature, and the consequent use of sharp curvature generally; the other, the improvement of track and locomotives making high speed possible.

"But while possible for the trackmen to line to a transition which improved the riding quality of road, it was even more difficult than to properly line an ordinary curve, and engineers, seeing the very general need which came along with fast speeds, heavy engines and cars, devised transitions to suit the purpose, and which could be laid off with instruments. There are many kinds, but they differ very slightly in detail, and are all alike in principle and operation. It is very easy to imagine that what is wanted is a curve which shall begin very gently and increase gradually until the same curvature is attained as that of the main curve, and for the elevation of the track to begin just about where the transition does and increase proportionately, so that there is always a perfect balance between the centrifugal force which on a curve makes the car lean outward, and the force due to elevation of outer rail which prevents it from doing so. Therefore, as the elevation must come in gradually from a level, the curvature should also

be worked in gradually, and this is why the transition curve is necessary and has been devised.

"Usually in new construction the whole curve is shifted inwards from the located line and the transition is fitted at each end. This permits the best and most rational arrangement. But on a line already built, it is not possible to throw the track off the roadbed so far as that method would require, but it is usual to apply such transition at the end of curve as can readily be done without throwing the track more than a foot or so. This must begin at some point on the tangent and end somewhere on the curve, and would probably never be much more than 250 feet long, although the length may be such as circumstances require.

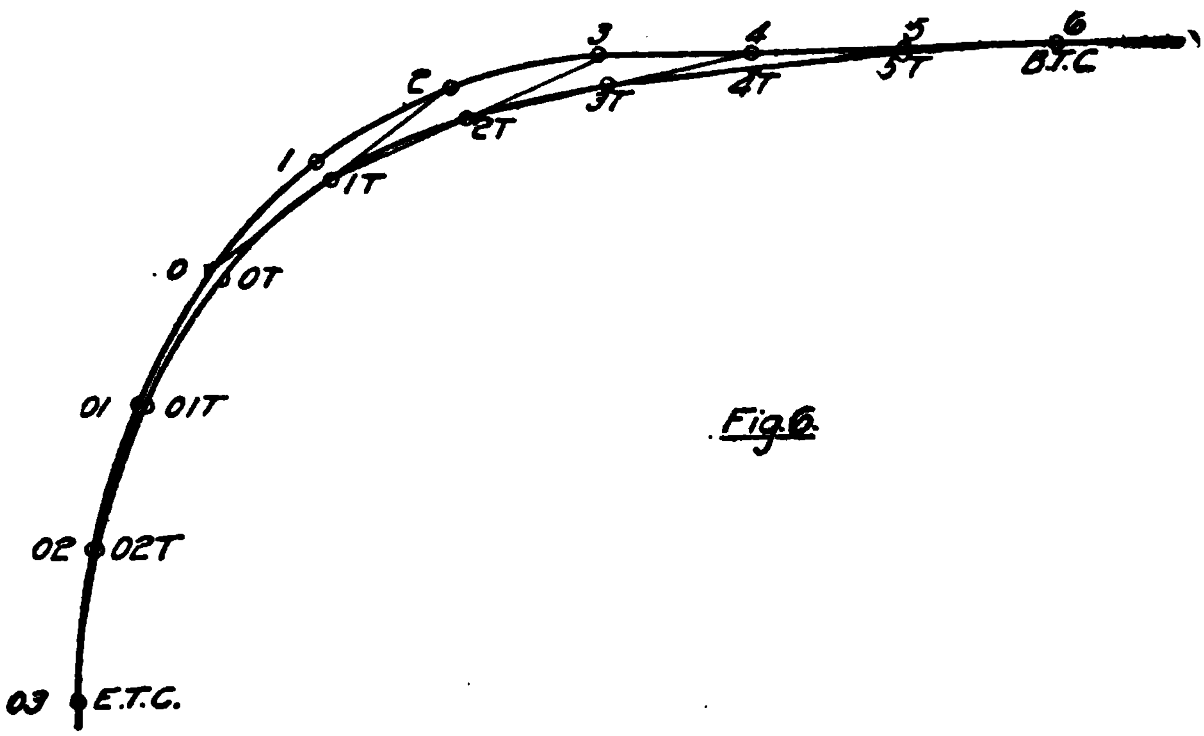
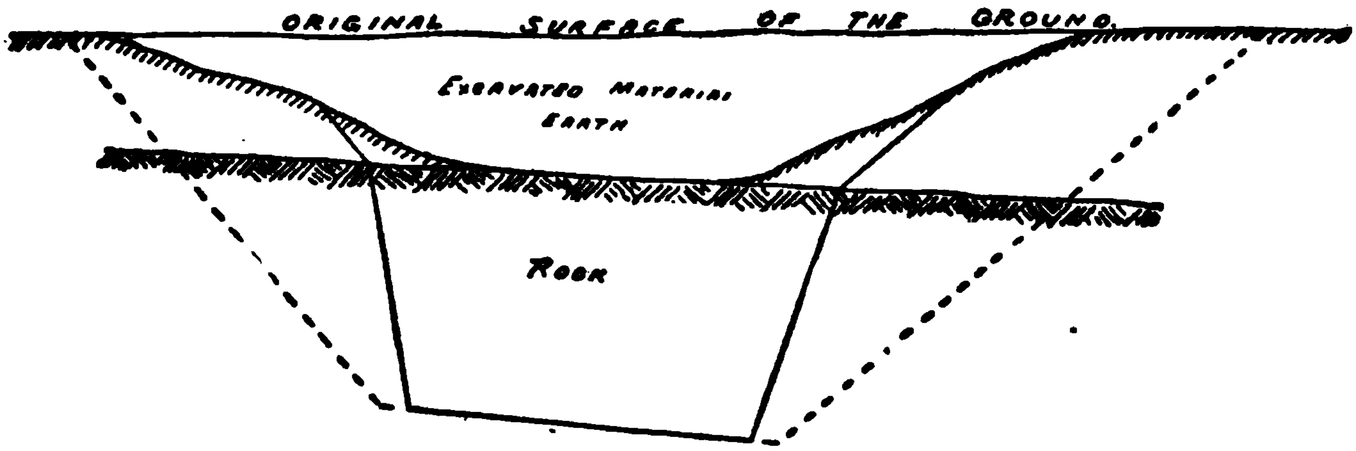


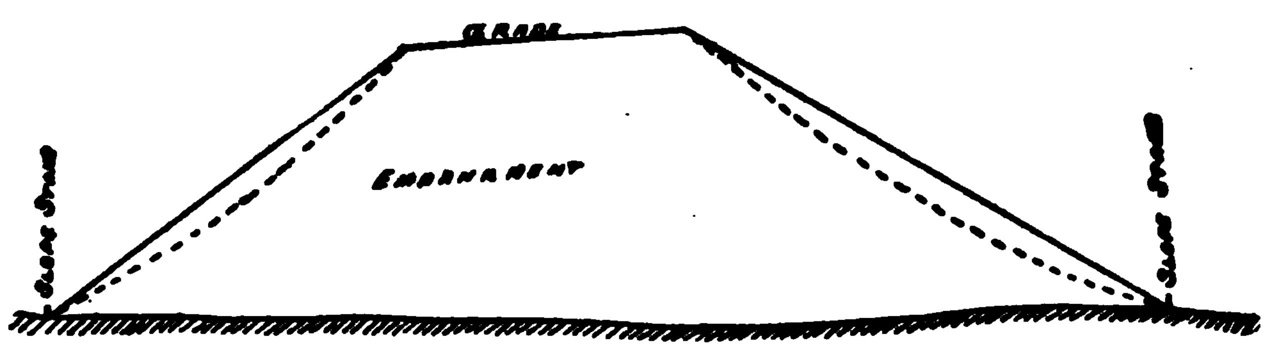
Fig. 57.

"To get a rule for a curve which can be very readily put in by trackmen on the ground, I have devised that shown in Figure 6. I do not claim that it is so good a curve as could be run by transit, but it gives one which is correct in principle and varies only slightly in detail

from the best possible. In Fig. 6, lay off from the B. C. along the curve three chords of equal length. The end of the third chord is point o. Continue marking off along the curve chords of same length as before, marking their ends o1, o2, o3. The last is E. T. C. Going back to o, mark the chords before measured, 1, 2, 3, along the curve and at equal distances, 4, 5, 6, along the tangent. Six is B. T. C.



SHOWING THE SLOPES FOR AN EARTH CUT.
The dotted lines show the slopes for an earth cut. The full lines show the slopes for a rock and earth cut.



Embankment; built full width at grade and out to the slope stakes.

Fig. 58.

"Draw a straight line o to 2, and mark the point on this line opposite 1, 1T. Draw line 1T to 3, and on it, opposite 2, mark 2T. Draw 2T to 4, and opposite 3, mark 3T. Draw line 3T to 5, and opposite 4, mark 4T. Opposite 5, lay off 5T at a distance from 5 equal to one-fourth that from 4 to 4T. Next lay off the dis-

stance from o to oT, equal to nine-sixteenths that from 1 to 1T—01 to 01T equal to four-sixteenths and 02to 02T equal to one-sixteenth the same. The curved line passing from B. T. C. through 5T, 4T, 3T, 2T, 1T, oT, 01T, 02T, and E. T. C., is the transition curve. The lengths of the chords may be such as will give satisfactory results, but in curves 6 degrees and less this length should not be less than 50 feet, unless the position of 2T is too far from the center of the roadbed. This is the greatest ordinate and, therefore, the length of chord may be determined very early in the process."

Running off Elevation.—As set forth and clearly explained by Mr. Burpee it is readily to be seen from the preceding explanations, rules and diagrams, that getting the proper elevation is as much a part of the transition as the lining of the curve is. In demonstrating this he explains the relations between transition curves and the change from the level track required on tangents to the elevated outer rail required on curves. He then proceeds to show how the conclusion has been arrived at in actual practice by discovering defects in the methods which, though useful under different circumstances, are not adaptable to the present high speeds.

He takes up this subject in his usual pleasing style, continuing as follows:

"We shall first discuss the method once very commonly used of placing full elevation at the B. C., and gradually tapering it off along the tangent at the rate of one inch to 50 feet.

"Fig. 7 represents the two rails of a track as seen with the eye on the same level as the track, the outer rail of the curve being shown by the dotted line and the inner by the full line. The incline portion AB of the

dotted line shows the making or developing of the elevation along the tangent at the rate of one inch to 50 feet. It should be remembered, however, that the forces

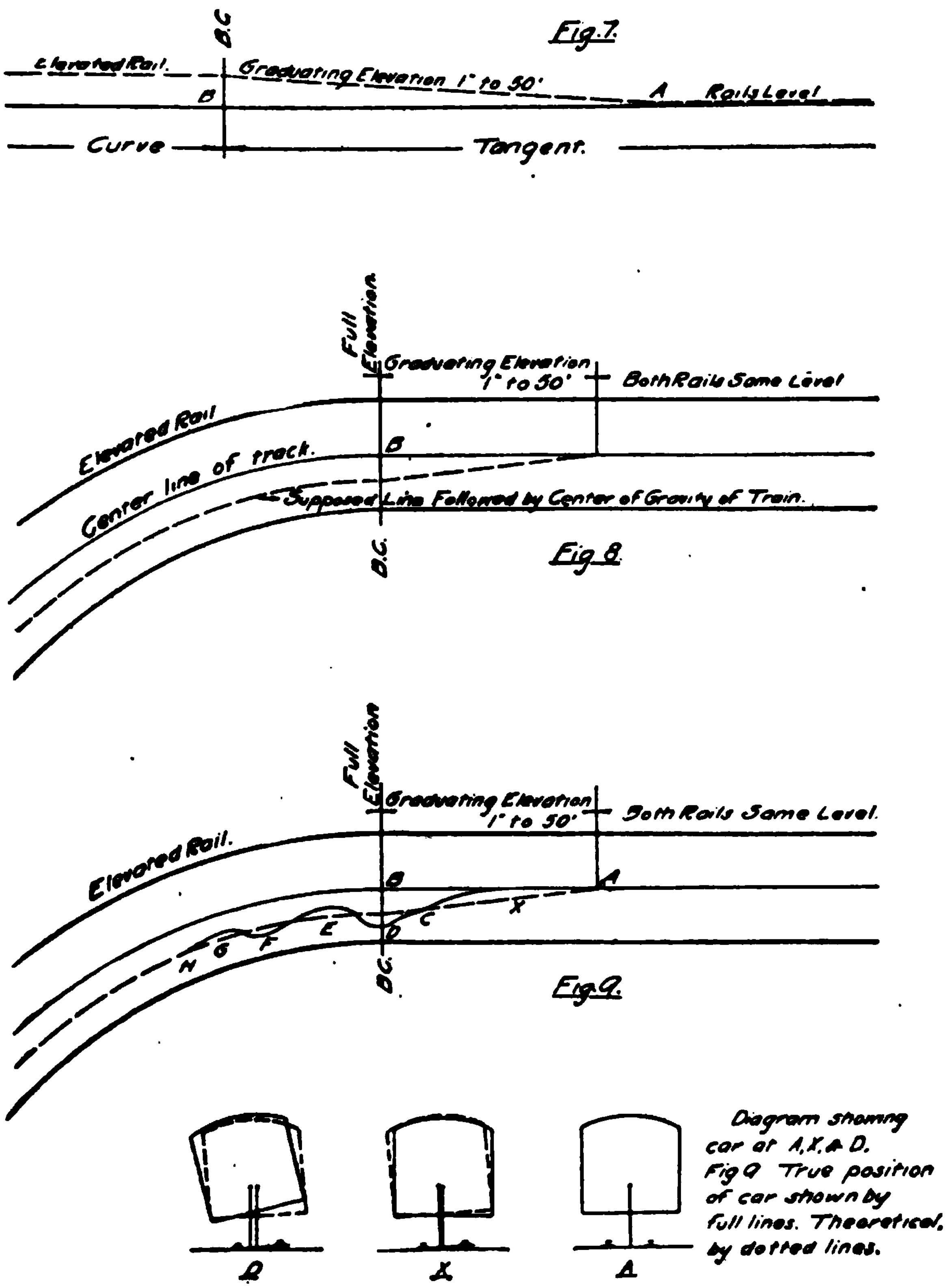


Fig. 59.

acting on the cars or engines to move them in any direction are concentrated at one point in each. This point is the center of gravity. In an engine this is about 7

feet above the rails, and in loaded cars, except where the loads are of very heavy substance, probably about six feet. Therefore, the elevation of one rail will move the path of the center of gravity to one side of the center by tipping the cars; and where the height is 7 feet, the distance to one side will be about 1½ times the elevation of the rail.

"Fig. 8 shows a track, a small portion of tangent and the adjoining curve, as seen from above, or as a plan view. It includes the portion in which the change from the tangent motion to the curve motion takes place, but without any transition curve applied, and with elevation made in the same way as Fig. 7. The outer rail is elevated, and the path of the center of gravity of the train is shown by a dotted line which is parallel to the curve; but at a distance about equal to one and one-half times the elevation to one side of the center line. This line, starting from the B. C., where it makes an abrupt angle with its direction on the curve, runs direct to the center of the track at the point where the elevation runs out, as shown by B. A., and there reaches the center line, where it makes another angle, and thence follows the center of the track.

"Now, suppose a train to be approaching the curve from the tangent; so long as both rails are on the same level, the center of gravity will be directly over the center of the track and in plain view it will be shown by the same line; but when the elevation of one rail begins the path of the center of gravity departs at A from the center of the track, and its departure increases to the point where full elevation is attained; in this case at B. C., where it begins to follow a line parallel with the center line, but at one side, as shown above.

"The law of inertia which tends to resist the movement of a body and also to resist its coming to rest when in motion applies to this case, so that the center of gravity of the train in motion on a straight line tries to continue on that line, and when a car arrives at A, instead of diverging immediately at the angle required by this method, still keeps on the tangent, owing to the elasticity of the springs until an amount of elevation has been reached sufficient to overcome its inertia, and to force the actual path of the center of gravity which we are now considering, to approach the line of its supposed path, namely, the dotted line AB. The car springs, which meantime have become more heavily loaded on the higher side of the car, in recovering also help to throw the car in that direction until the springs on the lower side resist and temporarily check further motion in this direction. This is illustrated by the first waves in the wavy line beginning at A and running toward the curve. This wave is shown as ending at C, where, because the two forces are nearly balanced, there is very little lateral motion, but increasing inclination of the car again disturbs the temporary balancing and gives a second impulse towards the low side, resulting in the second wave which reaches its height at D. Here the curve begins, and the centrifugal forces, aided by the compressed springs on the low side, result in a sudden righting movement to the car. This by its inertia goes to E, a little beyond the true position (the dotted line), but as there are now two pretty nearly balanced forces the waves of lateral motion grow smaller and soon entirely cease, the waves F and G showing this gradual reduction. These latter waves coming after the car has reached

the curve where elevation and centrifugal forces are balanced, are due to alternate action of the car springs."

Compromise Run-off for Curve Elevation.—Having explained why one method for graduating the elevation of the outer rail at the ends of curves is not a complete success, Mr. Burpee goes on to describe a method used without transition curves, one wherein the graduation of elevation takes place, partly on the tangent and partly on the curves. He explains that in practice some make the rule to have two-thirds the amount of elevation at the B. C., graduating or running out at one inch to 50 feet on the tangent, and gaining the rest of the elevation at the same rate on the curve. He states, however, that where the transition curve is not possible, he has adopted a rate of one-half at B. C., graduating to nothing on the tangent and usually at a rate of one inch to 50 feet, increasing it on the curve until the full elevation is made.

Accompanying this description is a diagram, Figures 10, 11 and 12, illustrating the relation between the center line of the track and the path followed by the center of gravity of the cars. He makes it plain by this diagram that no such lurching in the motion of cars at any speed is possible with this method as is shown to be the case when the method described in "Running off Elevation" is employed as shown in Figs. 7, 8 and 9. It will be seen that half the elevation is attained at the beginning of the curve, the car having only a slight tipping motion, which by its inertia increases its inclination though there be no further elevation in the track to aid it, but at this point the curve counteracts the tendency to further inclination of the car, and so the two balancing each other, permit the car to run with an even pressure on the springs, without any further increase or decrease of

inclination than given it by the track. The B. C. elevation at this point is not sufficient, it is true, as he points out, "but" he says, "we must remember two important facts which materially affect the necessary degree of elevation at this point." He then proceeds to further explain the method as follows:

"One of these is that the car does not feel the full influence of the centrifugal force due to running on the curve while the rear truck is still on the tangent; and until both trucks are on the curve it does not need full elevation. When the rear truck has reached the B. C., the forward truck in the case of a passenger car will have reached a point where the elevation is about or nearly an inch greater, so that in reality the center of gravity of the car when the rear truck is at the B. C., and is just receiving the full effect of centrifugal force is at a point where the elevation is about half an inch more than at the B. C., and consequently aids to compensate for the deficiency in elevation at the B. C.

"The other fact is that when a car in motion begins to run on the graduation of elevation in one rail, there is a sudden raising of one side, and the impetus thus given to it is sustained even when the force is withdrawn. The force in this case is not the elevation itself, but the increasing of elevation which tends to tip the car more as it proceeds towards point where elevation is full."

Or, as he explains, there is a greater force tending to throw the car against the low rail when it is proceeding along the graduated rail toward the full elevation than when it proceeds along a track one rail of which is constantly higher than the other, "by an unvarying amount." "Therefore," as Mr. Burpee points out, "when

running elevations into and out of curves this force which inclines the car toward the low rail should be taken into account." He then goes on to explain in what manner it is provided for by the method he recommends. It will be seen that the half-elevation at B. C. is provided for, the rest is gained at the usual rate after striking the curve, by referring to Figs. 10, 11, 12 and 13, this and the above principles are made quite plain. In further illustration, he says:

"Figure 11 shows in the dotted line the supposed path of the center of gravity of the cars, or the path it would make if there were no springs in them, and also by a full line, the center of the track itself. You will see that there is not any abrupt change in directions at A, B and C, as there are in Figure 8 at A and B. Figure 12 shows the corresponding lines of Figure 8, and Figure 11, side by side for convenient comparison. Inasmuch as the changes of direction of the moving load are made more gradually there is a corresponding improvement in the riding of the cars.

"Figure 13 shows also the supposed path of the center of gravity of the cars and the actual path of the same, due to their springs permitting a different motion in the body of the car from that in the truck. At first there is a tendency for the center of gravity not to be affected by the change in direction at A required by the beginning of elevation. When, however, the elevation increases to such an extent as to be noticeable, which will probably be near the time the forward truck has reached the B. C., and inward tipping motion begins, but at about the same time the curving motion begins also, and the centrifugal force is gradually applied and counteracts the inward inclination due to increasing elevation

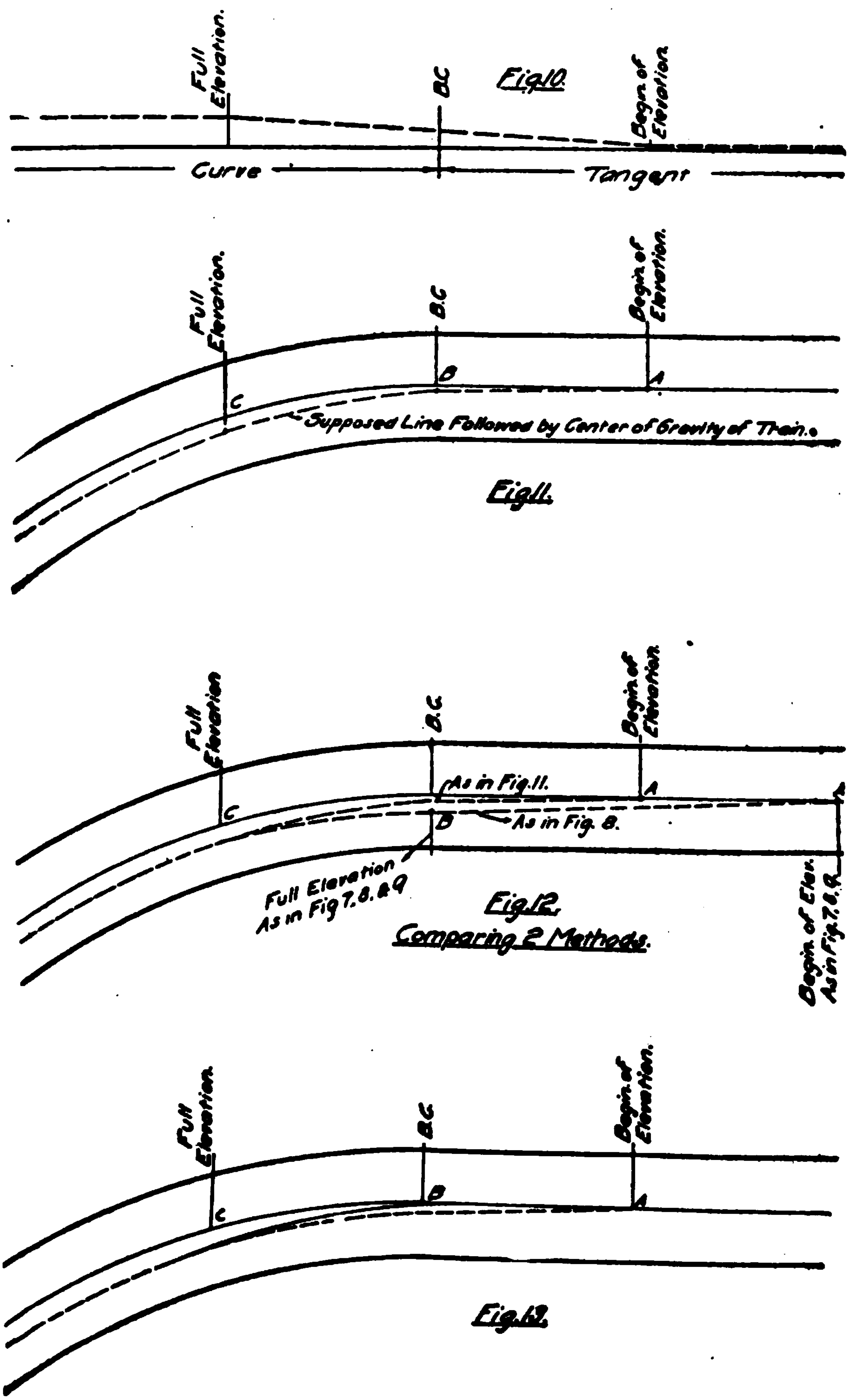

Full Elevation.
B.C
Fig.10.
Begin of Elevation.
Curve
Tangent
Full Elevation.
B.C
Begin of Elevation.
B
A
C
Supposed Line Followed by Center of Gravity of Train.
Fig.11.
Full Elevation
B.C
Begin of Elevation
C
As in Fig.11.
A
B
As in Fig. 8.
Full Elevation
As in Fig 7.8.& 9
Fig.12.
Comparing 2 Methods.
Begin of Elev.
As in Fig.7.8.9.
Full Elevation.
B.C
Begin of Elevation.
C
B
A
Fig.13.

Fig. 60.

and compressed springs on the high-rail side. The car is now in a position where, tending in one direction, the centrifugal force, and, therefore, the tendency of car to tip outwards, is on the increase. On the other hand, the elevation is increasing and along with it the spring pressure over the outer rail, which, with the momentum of inward tipping motion due to increasing elevation of the outer rail, tends to balance the centrifugal force and maintain a smooth motion in the cars. The improvement over the method previously shown is due to bringing the opposing forces into play at the same instant rather than one following the other, which would result in an excessive alternate swaying motion."

Results are, of course, always largely dependent upon methods, and to get satisfactory results, one should have the method right, that is the method should be as simple as possible in order that its principle may be easily understood. With a clear understanding of its principles the results of any method may be obtained. Hence, as he aptly says, "it would take time to make a scientific demonstration, but," he says, "I think the principle is quite simple and will be easily understood." Continuing, he goes on to state that the exact proportion of the full elevation which should be given at the B. C., will, of course, be subject to local conditions and so may be a little difficult to determine, "but," he says, "we can be sure the rule of one-half is a great improvement over the practice of full elevation at the B. C. Careful observation after its application may determine in some cases the advisability of slight change of the proportion of the elevation at the B. C., but it is likely that no great change will ever be necessary. It will also be noticed that the actual path of the center of gravity of the

cars will come pretty near to a transition curve and it is this we want rather than to make the wheels follow the same. It is seen that this path here is determined partly by the springs, while it would be better not to use them for that purpose unless unavoidable."

"We must remember," he says, "we are not to consider this method if it is possible to apply a regular transition, this method being as its name implies merely a 'compromise,' which may be used at points where regular transition was not provided for in the construction of the road, and where to now apply it would entail great expense."

He further says that taken in relation to "Running off Elevation," this method should be considered as an improvement over that therein described or "as a stage in the development of the ideal run-off."

Curved Graduation of Elevation.—This method, is, he states, a modification of the compromise method just described, in so far as it explains the increase of elevation. He illustrates it with diagrams and in making reference thereto, he also refers to some of the Figures in the diagrams already described. He calls attention to a resemblance between Figure 14 in this diagram and Figure 10 in a preceding one, because in both half the amount of elevation is made at the B. C., but, he points out, "instead of beginning at A and having it reach full elevation at B," the abrupt angles at A and B are rounded off "to avoid even small changes in direction," as are shown by Fig. 11 in a preceding diagram, illustrating "Compromise run-off."

In the compromise method a result approaching this was effected, "but," he says, "although an improvement over the method for 'Running off Elevation' as pre

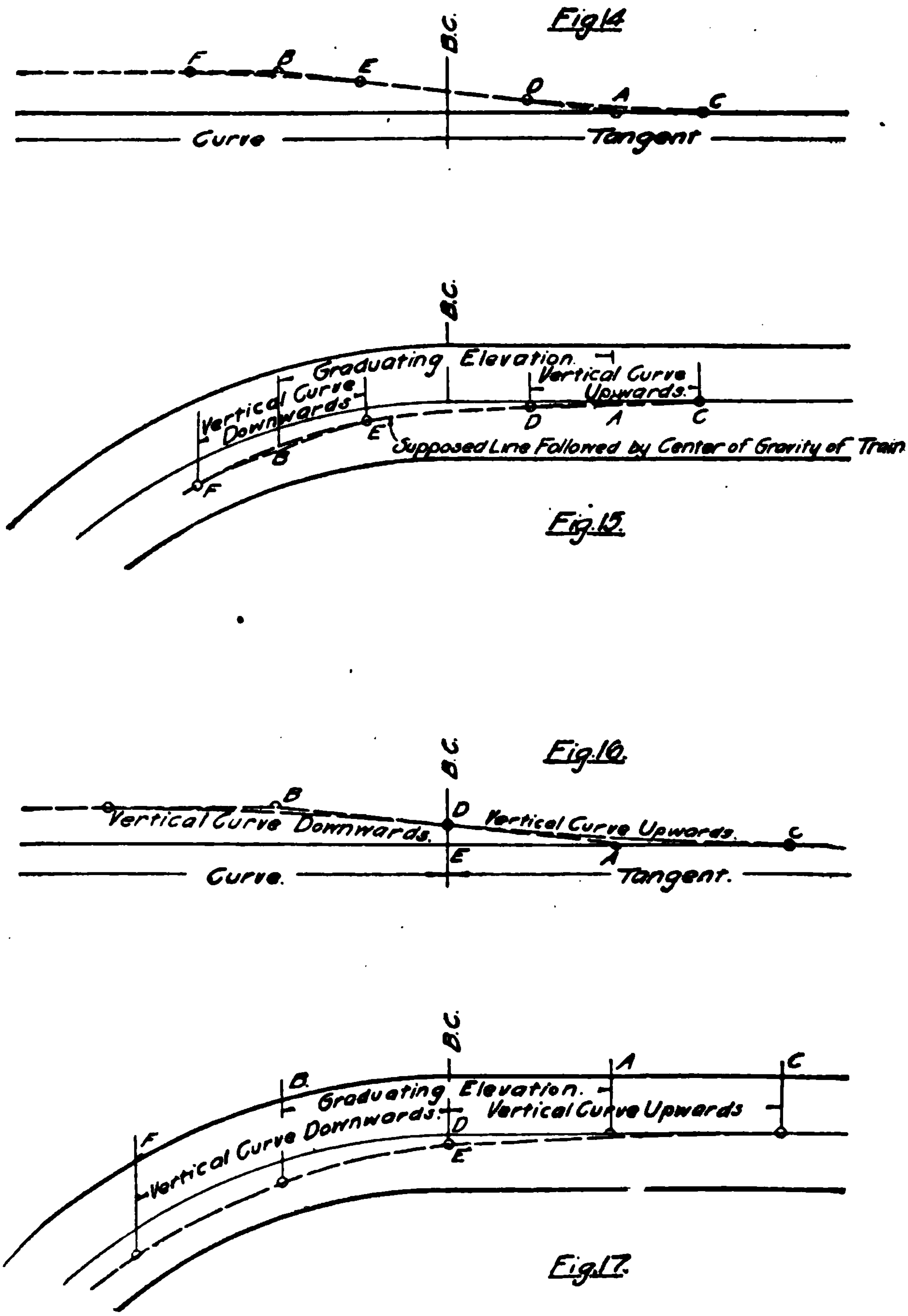


Fig.14
B.C.
F
B
E
D
A
C
Curve
Tangent
B.C.
Graduating Elevation.
Vertical Curve Upwards.
Vertical Curve Downwards.
D
A
C
E
B
F
Supposed Line Followed by Center of Gravity of Train
Fig.15.
B.C.
Fig.16.
B
D
Vertical Curve Downwards.
Vertical Curve Upwards.
C
E
A
Curve.
Tangent.
B.C.
B.
A
C
Graduating Elevation.
Vertical Curve Upwards
Vertical Curve Downwards.
D
E
F
Fig.17.

Fig. 61.

viously described, it is not quite free from decided, though small, changes of direction." An immediate or sudden change of direction by moving bodies from one course to another cannot be made without causing a stress within them, therefore, if the change of direction is made, as he points out, "gradually or through an easy curve, the stress is distributed both in time and distance and is not noticeable." He calls attention to what he explained concerning this in describing "Running off Elevations" as shown in Fig. 9, "the change of direction," he says, "due to elevation in track at A did not immediately produce a change in the direction of the car, but the springs over the elevated rail were compressed until by the combined force of the springs and inclined position of the rails, the inertia of the car, which at first tended to continued motion in direction of the tangent, was overcome and the car was thrown towards and finally beyond the correct position, its motion on account of action of springs being along a curved line. Without the aid of the springs the stresses on cars from the sudden changes of direction as above described, would soon cause their destruction.

"Here we have the choice of curving the path of center of gravity by placing the duty on the springs or on the track. The latter is cheaper and better. I think it is quite plain that Figs. 10 to 13, 'Compromise Run-off' show that much less spring work is done in passing through the graduation of elevation than had been done by the method of 'Running off Elevation,' and this simply by an arrangement that provides for a less abrupt change in direction of the path of center of gravity of the cars, and, therefore, with less tendency for the car to be impelled in some other direction by its inertia, than to fol-

low the path determined by the rail, as shown by Fig. 9, of a preceding diagram.

"Therefore, the rounding off of beginning and end of graduation, as shown in Fig. 14, will be followed by beneficial results, in that it causes the center of gravity of cars to follow a curved path without the help of the springs. By examining Fig. 15, you will see at A and B, the angles of the change in direction when these curves are not used and also the curve CD, made to round off the angle A, and the curve EF, made to round off the angle B. If you will refer to Fig. 13, 'Compromise Run-off,' you will see that the curve of the path of the car's center of gravity begins at B, and is produced by the springs, and although answering the purpose fairly well for trains of moderate speed, and a great improvement on older methods, is not so good as that here described.

"Referring again to Fig. 15, you will see that instead of the change in direction beginning at A, the introduction of the curve causes it to begin considerably earlier, but with a very gradual change, so that the full rate of graduation is not made until we pass A, and come to D, the end of the curve used for the rounding of angle A. The straight rate of graduation is then kept up until the point E, where the curve begins which is to round off the angle B, and gradually lessens it until it blends into the full elevation at F, without any perceptible shock. You will see that this method of making the graduation of elevation increases the distance and time, both of which are important factors in reducing stresses consequent on change of direction in heavy bodies. The increase in length of graduation shown in Figs. 14 and 15 is about 50 per cent, and I have described it for the

purpose of making it easier to understand a more complete method shown by Figs. 16 and 17. In Figs. 14 and 15, the part of the straight graduation between D and E is unchanged and remains the same as laid out from A to B. In Figs. 16 and 17, we suppose a beginning and end of graduation at A and B, but we introducc curves which meet at the B. C., so that the curved graduation which we are using touches the straight graduation nowhere except at the B. C., where the curve EF begins. We must know, of course, the full amount of elevation to be used, and therefore, the length of straight graduation AB. The length of curved graduation is double this, because the beginning of curved graduation is at C, and AC is equal to AD, and the end is at F, and BF equals BE. D and E are at the same point, namely the B. C., where one-half the elevation is used. The proportions of elevation to be given along the curved graduation at different points are as follows:

At the beginning C—none.
At A—one-eighth (1/8) of the whole amount.
At the B. C.—one-half (1/2) of the whole amount.
At B—seven-eighths (7/8) of the whole amount.
At F—the whole amount."

Curved Graduation Throughout.—This method is a continuation of the preceding method and was touched upon toward the conclusion of the description of curved graduation. This method when employed necessitates an upward curve for the first half, rising from the level rail, and a downward curve for the last half, joining the fully elevated rail in a direction parallel to the grade of the road. He states that "where the upward and down-

ward curvatures join each other, which in the method we have adopted is at the B. C., the rate of graduation is greater than at any other point, and is, in usual practice, one inch to fifty feet."

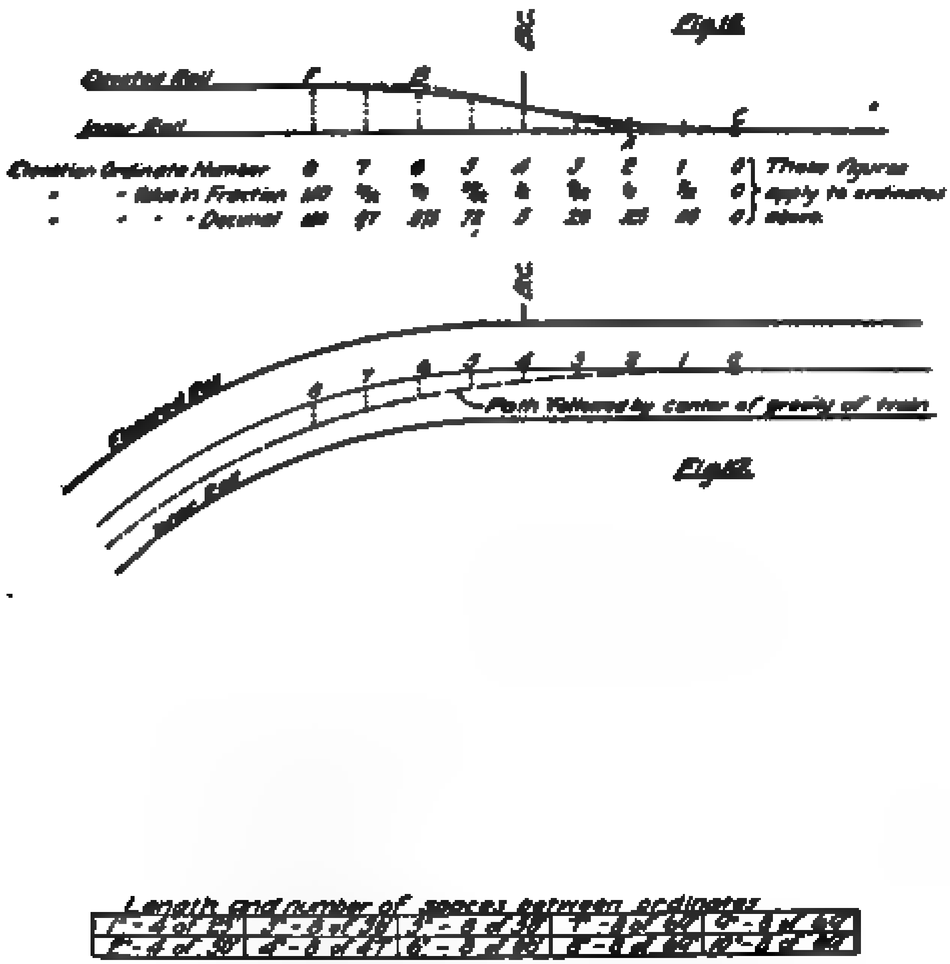


Fig. 62.

"Referring to Figure 18, notice that the elevated rail is represented by the curved line CF, and the regular rate, or straight graduation, by the dotted line AB. The line of figures 0 to 8 under the diagram refer to the points where the ordinates of elevation are made or to the ordinates themselves. The length, or, as we may say, the height, of the ordinates depends on the degree of

the curve, and will be found in Table 3, allowing the amount prescribed by our rules; namely 15-16 inch per degree. There are exceptions to this, for in 1-degree and 2-degree curves the table gives 1 inch to the degree. The additional 16th or 8th of an inch in these cases would not be noticeable where the elevation is so small, even if it were possible to work so close in surfacing. In 6-degree curves the elevation used is a little less than the rule. In curves 7 degrees to 10 degrees the amounts are equal, because when the elevation is so great as in these curvatures the amount of inclination in the cars is excessive and uncomfortable unless at higher speeds than usual on such sharp curvatures. It is well to remember here, that within a certain limit the elevation does not increase in proportion to speed; but in proportion to square of speed; that is, suppose at 40 miles per hour, you need two inches elevation on a 2-degree curve, at one-half the speed you would want one-quarter that elevation, or one-half inch; the square of 40 being 1,600, and the square of 20 being 400, or one-fourth. An exception to the rule is necessary, therefore, in very sharp urves, for two reasons, viz.: great elevation shifts the load of the car too far to one side, overloading the springs and producing bad effects on the low rail; and, the general and safe practice of reducing speed on sharp curves.

"The length also of the space between the ordinates depends upon the degree of the curve. For the length of straight graduation it is usually 50 feet for each inch of elevation, and in the curved graduation, Fig. 18, it is, as explained in 'Curved Graduation of Elevation,' twice the length; therefore, the total length in feet of graduation is equal to 100 miltiplied by number of inches in ele-

vation. In 1-degree and 2-degree curves we make only four spaces, but on curves sharper than 2 degrees we make 8 spaces. The length of these spaces is shown at the foot of Table 3.

"Although it is probably best not to make these spaces much shorter than the table gives, we can, in exceptional cases, do so. Such exceptions might be on curves which reverse, or where the tangent between curves of opposite direction is too short to allow the proper proportion of the graduation to be made within its length. Again, it has already been pointed out that the only place on the curved graduation where the rate is as great as the straight rate is at B. C., and even here, supposing the center of a passenger car with truck centers 40 feet apart to be over the B. C., one truck center will be 20 feet on the upward curve and the other 20 feet on the downward curve. The straight rate of graduation would in 40 feet amount to 13-16th of an inch, but on the curve graduation it will be, for reasons above mentioned, but 11-16th of an inch. True, this difference does not amount to much, but I mention it more to point out the fact, so that the character of the graduation will be better understood.

"In determining the length of the spaces between the ordinates we must consider the action of car springs, as these are the means used for easing the motion of cars over irregularities of track. The freight car of to-day has a base from center to center of trucks of about 30 feet; most are shorter and a few are longer, but we can use this in our consideration. At 50 feet to the inch the amount of graduation between centers of trucks as above would be 30-50th of an inch, or about 5/8th of an inch. The usual allowable working deflection in freight car

springs is one inch. This does not take up the entire play, but as much as it should, as we never want the springs to come close together, for then they are useless. This deflection would in extreme cases permit 2 inches graduation in the distance between truck centers, or 30 feet. But we propose, as a rule, to use only 3-10 that amount rated at 1 inch in 50 feet. For passenger cars the springs are more flexible even than this, so it will be safe to say that a passenger car will go where a freight car will."

"The conclusion we should draw from this is not that we should make our graduation as short as the car springs and the distance between trucks seem to indicate as allowable, but that we should be cautious in changing a rate proven to be safe. We also know from experience of cases which do not admit of the regular rate being used, that a quicker rate will work all right, but in as much as there is discomfort if not actual damage caused by cars tipping very much towards the low rail, there is good reason for making the graduation as short as practicable, and a good proportion of it on the curve itself. It is only by careful experimenting that the proper proportions are arrived at in such experimental cases. When these have been ascertained, adopt them generally in similar cases.

"By referring to Figure 19, which shows the track as seen from the foregoing, you will notice that the positions of ordinates are marked from 0 to 8, as in Fig. 18. Point 4 is at the B. C., but the center of gravity of the cars begins to make a curved path at 0, where the curved graduation begins and follows an easy curved line, blending naturally into the regular curve at 8, instead of at the B. C. From 0 to 4, the wheels are still on the tan-

gent, but owing to the curved graduation, the motion of the body of the car is in a curved line, and the centrifugal force due to this counteracts its tendency to tip over toward the lower rail. From 4, the B. C., of the track, the rate of graduation diminishes, and this results in a diminishing rate in curvature of the path of the center of gravity of the car until it equals that of the curved track after the point 8 is reached where the elevation is full; and from this point through the curve, the path of the center of gravity of the cars is parallel to the center of the track. This method of graduation effects a transition of twice the usual length of the graduation. Although not lined in the track and not affecting the wheels, it does affect the loads, and that is the principal thing. This transition curve in center of gravity path starts at 0. At the B. C., the rate of curvature is a half that of the curve of the track, and at 8, is equal to the same.

"As before mentioned, it is not intended to make this take the place of a transition curve which should be built into the road, but it can be made to answer the purpose fairly well where none has been provided for, and the object of this (as well as the previous papers), is to enable trackmen to help themselves when circumstances require it."

Application of Transition Curves.—Under this caption Mr. Burpee makes a brief review of the main points of the transition curves mentioned in the different methods described by him, and then he goes on to describe a method in common use. To explain what he means he says:

"Figure 20 shows a curve fitted with such transitions as are described in 'Transition Curves,' and it is also

similar to all the transition curves which are applied to track laid on a roadbed on which none was run before grading, but where the main curve runs from B. C. to E. C., on a true circular arc. On each end the transitions B. T. C. to E. T. C. are run, so as to begin the graduation of elevation at or near the B. T. C., and gradually in-

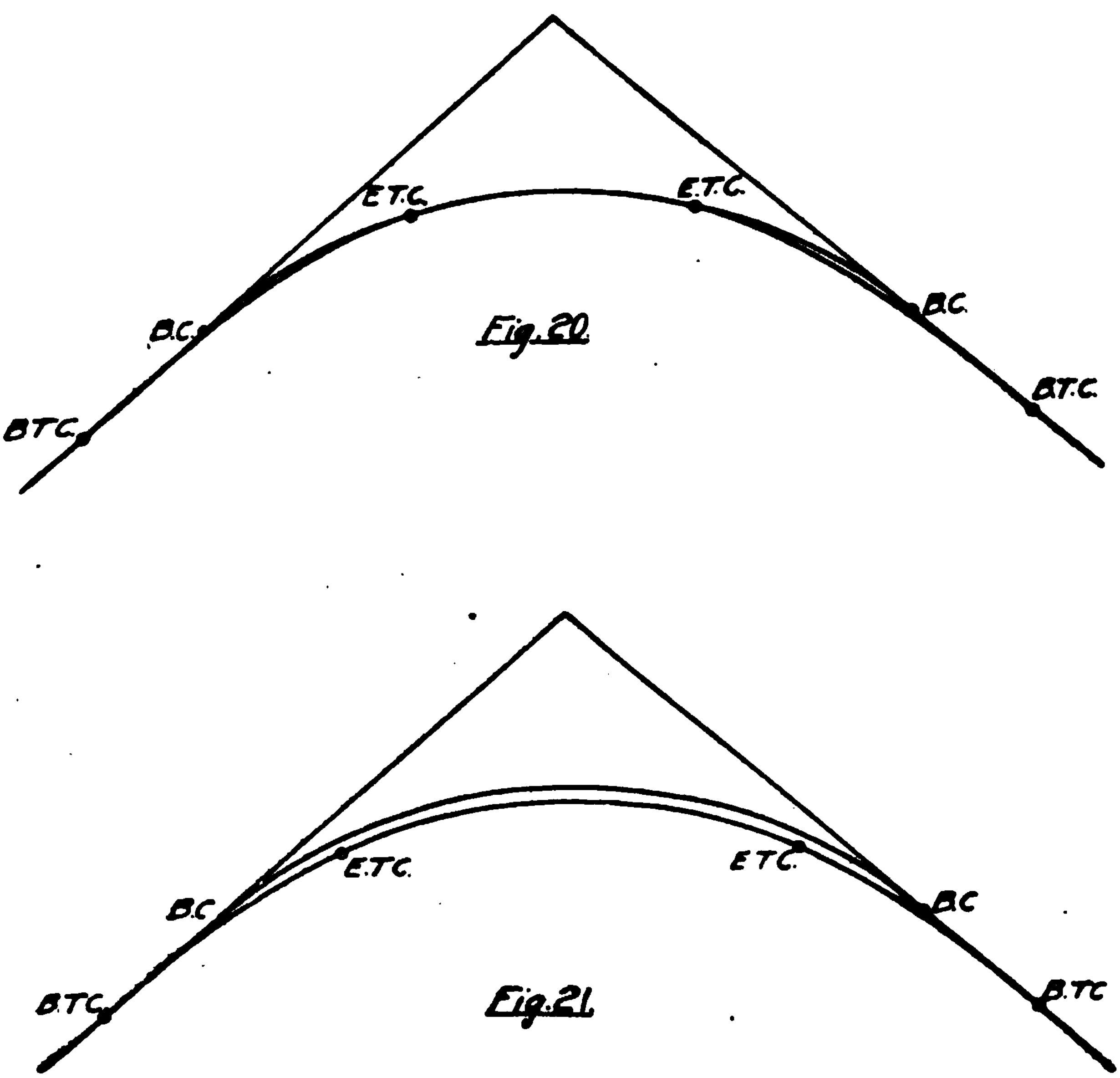


Fig. 63.

crease it as the transition becomes sharper until attaining full elevation at E. T. C. The worst fault with this is that at the E. T. C., it must be a little sharper than the main or original curve.

"The only way to avoid this is as shown in Fig. 21. The original curve is from B. C. to E. C., the outside

curve. You will see that no part of this is used when the transitions are run in, but that the middle portion between B. T. C. and E. T. C. is a little inside and parallel with the original, and is, therefore, a trifle sharper than it, but the increased curvature is immaterial, and it has the advantage over Fig. 20, in the fact that there are no sharper places at the end of the transition than in the middle or main portion of the curve.

"In the method of 'Curved Graduation Throughout,' the line followed by the center of gravity of the cars is similar to this but that method comes far short of giving so good a result as this.

"This transition begins with a short arc or chord of 1 degree and is followed in order by arcs of 2 degrees, 3 degrees and so on. The arcs are of equal length in any one transition, but this length may be such as circumstances determine. Excellent results are obtained by 25-foot chords, which do not require a great distance or offset to separate the inner curve from the original. If we are, however, obliged to graduate the elevation 1 inch in 50 feet and begin at the B. T. C., it would be necessary to mark the chords about 50 feet long. In moderately sharp curves the difference in length of offset between this chord length and 25 feet would not be noticeable, but in curves of 5 degrees and 6 degrees it would be considerable and in some places the greater offset might be objectionable. Therefore, I have adopted 25 feet as being the shortest length permissible, and yet long enough to fairly accomplish the desired result. The rule for graduation with this is to have 1 inch elevation at the B. T. C., and to increase elevation at the rate of 1 inch to 50 feet until full allowance was attained. This comes usually beyond the E. T. C. In other words, the length

of the graduation is greater than the length of the transition, and a part of the excess of length lies beyond each end. That is, it begins before the transition does, and ends after. The advantage of the 50-foot chord lies in the transition and elevation beginning and ending at the same points.

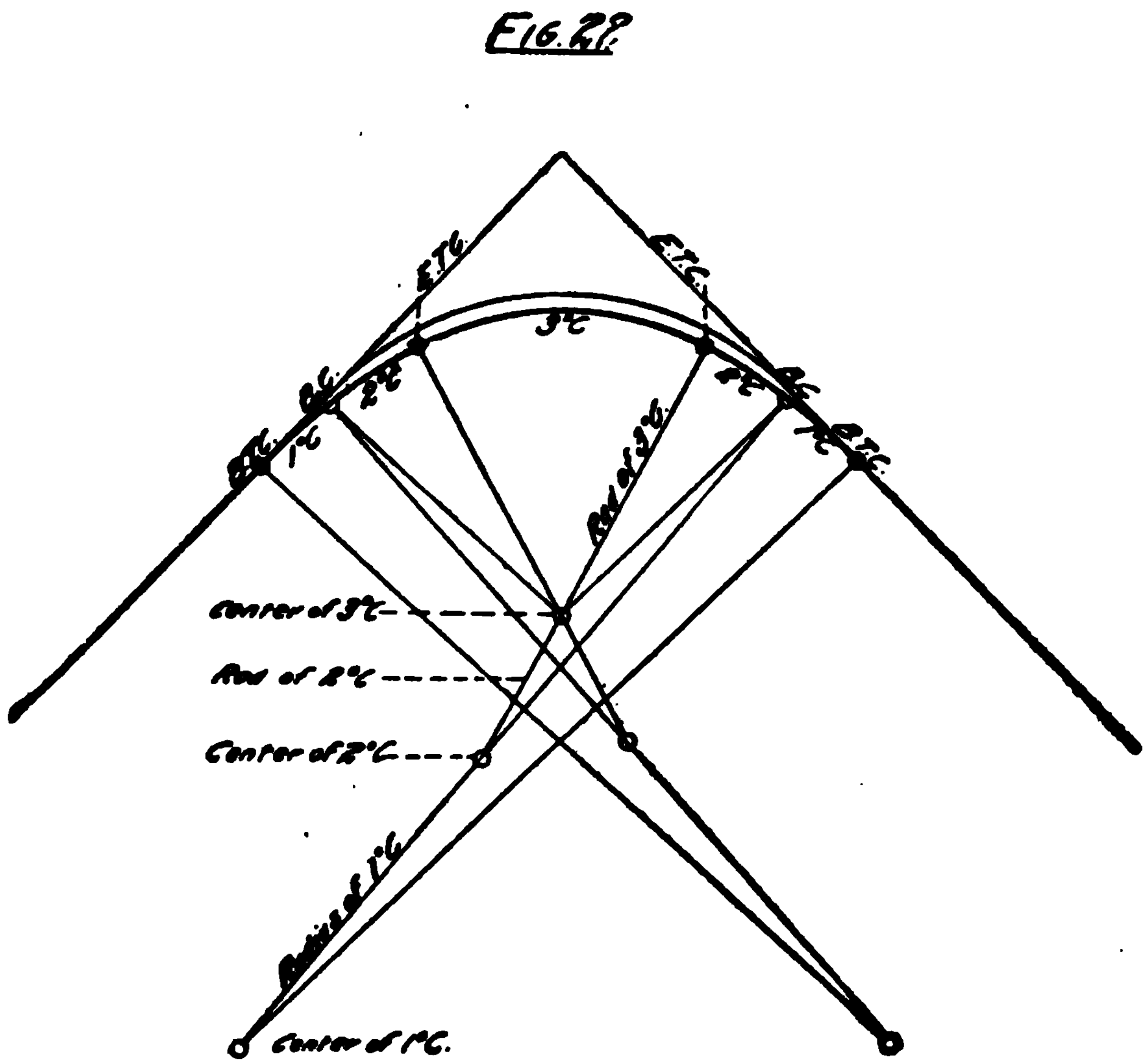


Fig. 64.

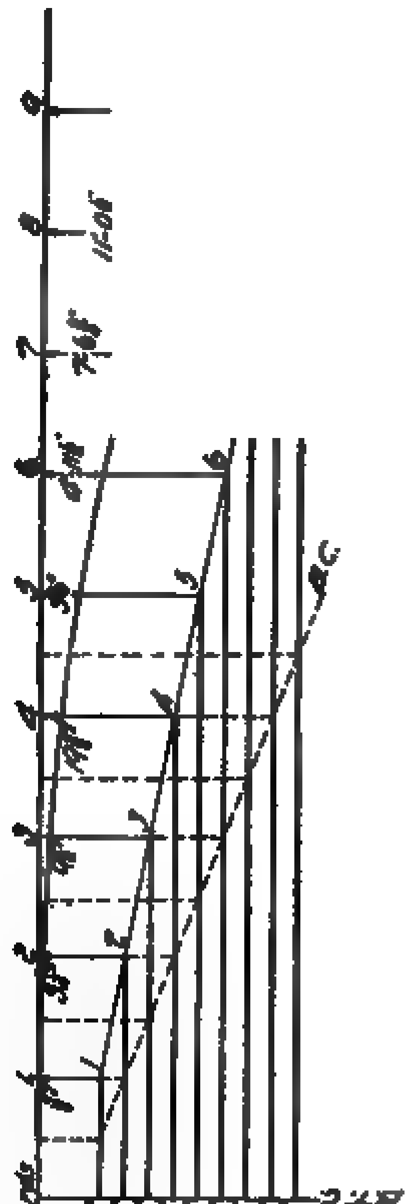
"The number of arcs or chords in the transition is one less than the number expressing the degree of curve. For instance, a transition of 3 chords is required for a 4-degree curve. The curvature thus progresses: 1, 2, 3, 4. The first half of its length is on tangent and the last half on the original curve, thus for a 4-degree curve and transition chord 25 feet long, the total transition length

will be 75 feet, and it will begin on the tangent 37½ feet before coming to the B. C., and end on the curve 37½ feet beyond the B. C. See Fig. 23.

"Figure 22 shows a 3-degree curve with transition applied at each end, two chords—a 1 degree and a 2 degree. The radius of each chord is shown, and you will see that the center of any arc always lies in the radius of the preceding arc. When longer chords than 25 feet are used, the ordinates are also longer, as follows: A chord of 35.4, ordinates twice; 43.3, three times; and 50 feet four times, as long as those for 25 feet.

The dotted diagonal line marked B. C., intersects the horizontal lines at their middle points, and the dotted vertical lines from these intersections point to the position of the B. C. of a curve relative to its transition, showing that one-half of the transition is on the tangent to the left of the B. C., and one-half on the curve to the right of the B. C. Where such a transition has been put into the track it can be relined by the following: The first thing to do is to find the degree of the curve by stretching a cord 61 ft. 8 inches in length along the side of rail, so that middle of cord is about opposite the middle of the rail. This will give a better average middle ordinate than if it were taken near a joint, for the reason that if the track is not well lined the errors in line are usually greatest at the joints. The number of inches in the length of this middle ordinate is the same as the number of degrees of the curve.

"Second: Stretch a cord along the outside of the outer rail on the tangent near the B. C. so as also to extend along the curve two or three rail lengths, but in a straight



According as the length of chord varies the given tangent offsets must be multiplied by the following factors.

Chord	Factor
25.'	1
35.4'	2
43.3'	3
50.'	4

Fig. 65.

line. This cord may be in line with the base of the rail and just above the spike heads. See Fig. 4.

"Third: From Fig. 23 find the ordinate or tangent deflection at the E. T. C. of the transition for this curve.

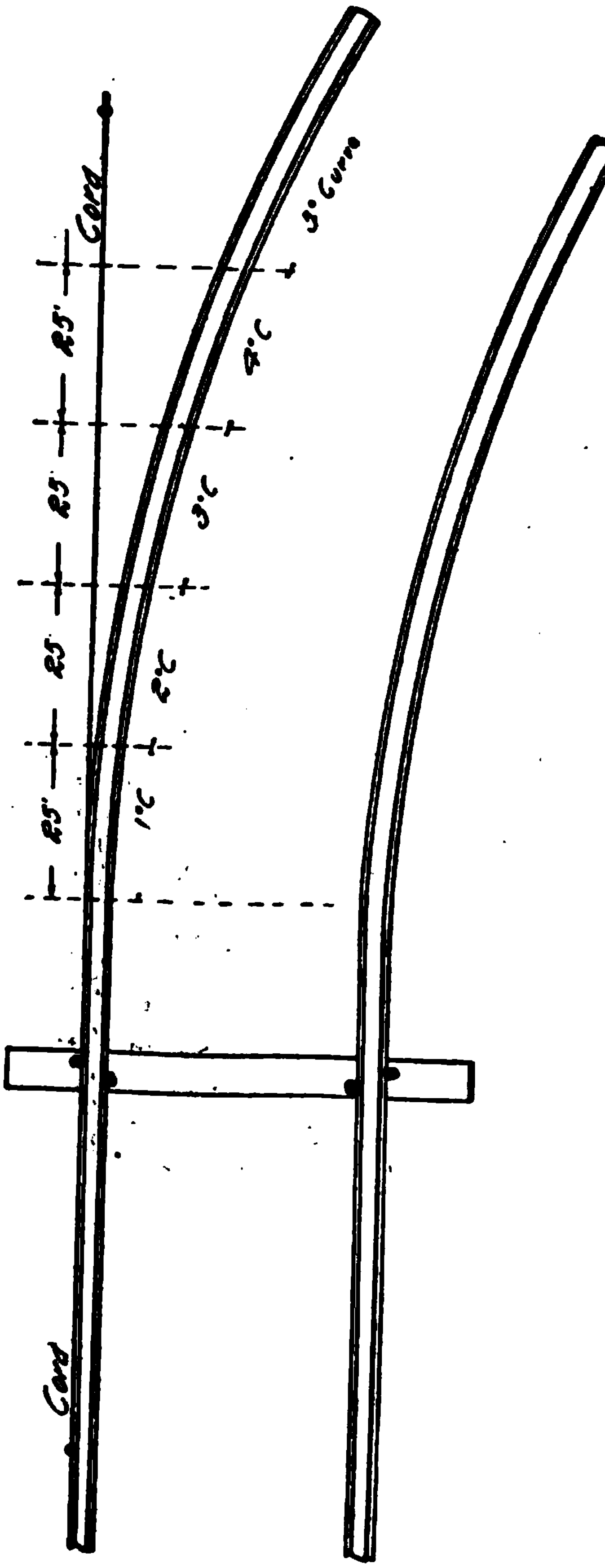
"Fourth: Find the place where the distance between this chord and the base of the rail is equal to the ordinate or tangent deflection at the E. T. C. and stick a nail there on line with the tangent; and find if the other ordinates or tangent deflections between this and B. T. C. are of correct length, as shown in Fig. 23, measuring them at points 25 feet apart or at distances equal to the length of the chord used in the transition. See Fig. 24.

The methods described by Mr. Burpee are, as he states, descriptive of "the lining of curves; the elevation of the outer rail on curves; and the transitions at curve ends for the purpose of changing the motion of cars from tangent to curve, and curve to tangent easily and naturally."

It is one thing to put a track into any specified condition desired but it is quite another thing to keep it in the same condition and maintain perfect line and surface.

Many things combine to counteract the efforts of trackmen. One of the most common of them is the "heaving" of track. Regarding this and how best to remedy it, he says:

"In summer, when the roadbed is dry, the track may be in the very best condition and yet the same track in winter may become dangerously rough. The reason for this is that any soil which contains moisture expands or swells in freezing. That which contains least moisture expands least, and that which contains most, expands most. While it is absolutely dry no expansion takes place, no matter how cold the weather may be, but absolutely dry soil is almost never found. Frequently soils of



Note:- Not drawn to scale, but to illustrate the method of finding transition points for a 5° Curve.

Fig. 66.

different capacities for holding moisture are found close beside each other. Here there will be different rates of expansion every few feet, and as usually the only direction possible for expansion to occur is upward, we find what we call "heaving by frost" taking place and throwing the rails very much out of surface, but sometimes also out of line.

Fig 67. Widening Embankment.

"Should the soil be of uniform nature as to its capacity to hold moisture the heaving actually done would not be noticeable, because all had expanded uniformly. The need of shimming therefore is almost or entirely due to the variable nature of the materials in the roadbed under the ballast.

"In grading the roadbed, owing to the uneven or wavy natural surface of the ground, the grade must frequently intersect this surface sometimes being below it, as in cuttings, and sometimes above, as in embankments. Usually the earth or other material excavated in cuttings, where surface is above grade, is used in building the embankments on those portions of the ground surface which are lower than grade. The foot or two of surface is usually loam, while underneath the loam there is a bed of subsoil or hard pan. The surface loam is more spongy and will hold much more water than the subsoil, and consequently will, when frozen, be expanded more than the subsoil. Where a cut is more than 1 or 2 feet deep the grade usually passes into the subsoil; but where it enters and leaves the cut and also on the adjoining portion of the embankment which was made of loam from the nearest part of the cut, it will be found in almost all cases that the frost will heave the track badly. That is what really happens at each end of the cut and where the embankments are shallow. It is due to the larger proportion of frozen moisture in the soil at these parts of the road. At the same time it is noticeable that the part of the cut where the subsoil has been penetrated will usually have been heaved a very little or that the heaving is so uniform as to be not noticeable. The same is true of the adjoining embankment where its depth is sufficient to permit drainage, and is due to the very small amount of moisture contained in it.

"It will be noticed in cuttings where there are very shallow places, and where loam has been left in the roadbed that here heaving will take place to a greater degree than in deeper parts of the cutting. Also, in the shallow embankments of varying depths, that considerable heav-

ing will occur where it is very shallow; that is, so shallow that the frost will penetrate to the loam under the embankment. Two things must combine to produce heaving, namely moisture and freezing.

"There are occasionally cuttings in which, even where quite deep, the track will heave badly. A large boulder, if the frost gets under it, will sometimes be forced up. Sometimes a solid ledge preventing drainage will cause it, though a seamy ledge with vertical strata seems to afford fair drainage which obviates it. Frequently, too, heaving is due to clay streaks in sand or gravel cuts.

"The remedy possible to section men is, of course, to drain the road as well as possible. It is likely that a ditch 2½ feet below the base of rail would almost entirely cure the trouble. But it is possible that even after this some places may have to be 'dug out'; that is, the light porous soils, clay or boulders must be removed from under the track and replaced with gravel.

"Plenty of ballast, of course, will do more than any other one thing except ditching. But ditching and digging out should precede ballasting in order to secure the best results."

TRACK NOTES BY PRACTICAL MEN.

Economy in Track Work.—Expressing his views on this subject to a convention of roadmasters and trackmen, Mr. C. H. Bowen, roadmaster, C. & N. W. Ry., wrote:

"Economy in track work is the frugal and judicious use of material, tools and labor. To practice economy is to avoid waste.

"We will first consider the use of tools and material.

About all that can be said is: Do not waste anything. Do not carry on hand tools or material for which you will have no use.

"Keep close check on your foreman's requisitions and monthly material reports. Before forwarding a requisition for anything, be sure that it cannot be found on hand at some point on your division.

"Keep all sections well supplied with necessary tools and material. If this is not done, the foreman cannot work his men to advantage.

"If possible, keep your hand-cars in first-class, easy-running condition. Do not carry a large amount of surplus or emergency material on each section, but keep a full supply at a few important points from which shipments can be made quickly.

"The proper use of material depends very largely on the section foreman. He should give the matter close personal attention, see that all material, both usable and scrap, is properly taken care of and entered on monthly report. Do not take out of the track any material which has not outlived its usefulness, nor ship away as scrap any usable spikes, bolts, nut locks or angle bars.

"The general impression is that all scrap is sorted at the shops and that none of the usable material is lost sight of. While this is probably true, the proper place to do the sorting is on the section where the material can be used. Material not suitable for main track can be used to advantage in unimportant sidings, spurs, temporary tracks, etc. Every division has more or less of this class of tracks, and we have all seen boarding cars set out on tracks built of good rail, new spikes, bolts, angle bars, and even new ties. This is certainly not an economical use of material.

"Do not lose sight of the fact that every piece of scrap iron has a money value; pick up everything you see. The thought often occurs to me that if every old bolt and spike were a new copper penny we would see fewer of them lying around on the right of way.

Economy in Labor.—Here we often find it necessary to spend money in order to exercise real economy. If you have a gang of twelve or fifteen green laborers on a section, give the foreman an assistant and do not expect him to raise track, put in ties and do other work to advantage without it, for there are some things that even a section foreman cannot do. If the gang is increased to seventy men, give him a time-keeper and all the assistant foremen your superintendent will stand for. A common mistake is to have too little intelligent supervision. This is what we must have and it is money well and economically spent. If you have a work train doing any kind of work, assemble all the men you can work to advantage. If you have thirty carloads of ties to distribute on your division, instead of working two days with a small gang of men, get together men enough to finish in one day. You thus save the expense of the engine and crew for one day and incidentally give the train dispatcher one day's use of the engine and free the fifteen cars one day earlier. In these strenuous times this is a big item.

"On the other hand, if you have a few rails to load at some point, send just men enough to handle the rail but no more. A tracklaying gang to work economically should be just large enough for the work to move along smoothly all the time, each man doing the same work all the time. The exact size of the gang will depend to some extent upon the kind of men.

"In closing, a few suggestions to section foremen. Before it freezes up in the fall, see that all necessary ditches are cut to properly drain the switches in your yard; do not wait until you are obliged to pick frozen ground. In gauging track in the fall and winter it is not necessary to spend time and use material in plugging spike holes in ties that will be taken out of track the following spring. If you are working 6 or 8 men, do not keep them all on the hand car in your daily trip of inspection over the section; you can surely leave part of them where the day's work is to be done and outline enough work to keep them employed until you return. If, when you have the entire crew on the hand car, you discover a broken fence board or wire, broken bolt in frog or switch, or any of the numerous small things you find every day, do not go at the work with the whole crew, but leave one or two men to make the repairs and go on to your regular work with the balance of the men. Some men will accomplish little enough if they are placed where work is staring them in the face, and the foreman is pounding them on the back, we should certainly avoid placing them in positions where they cannot find work if they are looking for it. I venture to say that we have all seen four and even six men trying to put a pair of angle bars on a joint or replace a broken bolt, in most of these cases the foreman doing the greater part of the work. In rare cases we see a tendency on the part of the foreman to exercise too much supervision. It is poor economy for a foreman to stand around in the winter and direct the work of one or two old, experienced men in cleaning out switches and crossings, gauging and shimming track, or other work. This is one of the cases

where the roadmaster puts in his oar and pulls for economy."

Relaying Track.—Relating his own experiences regarding relaying rails Mr. Peter Stafford, roadmaster, C. & N. W. Ry. (lines west of Missouri river), wrote:

"The first move is to unload steel properly so as to minimize time in laying. In my experience I have found that a great deal of time is saved by getting steel properly distributed. Fastenings should also be placed at the same time. A roadmaster should always select one of his most reliable foremen to lay steel. The success of the work depends greatly on this. A capable foreman can work from forty to fifty men to good advantage. When old rails are removed from track, ties should be adzed so as to get a good level bearing for new rails. We find in many instances that old rails on soft wood ties will roll, or turn out. Expansion is an important feature to consider in laying track. The proper expansion shims should be used in every joint. Climatic changes should be very carefully watched in laying steel. Foremen should be well supplied with all sizes of expansion shims, and should also be supplied with a thermometer.

"Expansion shims should not be taken out until joints are bolted. Each day's laying should be finished completely, that is to spiking and bolting. I have found that sometimes foremen are apt to neglect some of this work, letting it go for several days, which causes the rails to "creep" or "run," causing poor expansion in the joints.

"Joint ties and base plates should be put under joints, and track gauged as quickly as possible, the force doing this work not being more than a mile in the rear of the laying force, work being done by a foreman and a force

of about thirty men. Of course when relaying track in the winter, joint ties cannot be put in.

"Track should be spiked in full, and every slot hole should be spiked in ties that come under angle bars. About thirty days after steel is laid, track bolts should be all gone over, and retightened.

"With the force I have named, and with good weather, a foreman should lay and complete one mile a day. In closing, I would say that the greatest care and caution should be exercised in making connections with new and old steel at the end of each day's work to prevent any accident during the night."

The Northern Pacific follow the following rules when relaying track:

"When relaying track, a convenient method of unloading rails from end of car is by means of two 30-foot lines, equipped with grab-hooks on each end, one end to be made fast to joints and the other end to slots in end of rails, using the engine for moving the cars. This insures proper spacing, and is more economical than unloading from the sides. Use roller at end of car when drawing off rails.

"Distributing rails.—The rails may be distributed either from end or sides of train. If distributed from the sides, both ends of rail must be dropped simultaneously. Skids will invariably be used whenever necessary to unload into piles. In all cases the greatest care must be used to avoid injury to rails by dropping them on hard substances or uneven surfaces."

The Secret of Good Track.—"Good Track," says Mr. M. J. Deltgen, a roadmaster in Iowa, "lies largely with the men in charge of it. No matter how good the material you have to build the track with, it will not be

good track unless laid by men who thoroughly understand their work, and it will quickly become poor track unless it is watched closely and given proper care. These duties fall to the roadmaster. It is 'up to him' to see that his track is in the very best of shape. Every section foreman on his division must be a thorough track man and capable of handling the men over whom he is placed in charge. The roadmaster must keep in constant touch with the foreman, point out the bad spots and give him such information and suggestions as will help him to keep his section in the best shape.

"The season of work on track is from the time the frost comes out of the ground in the spring until the ground freezes up in the fall.

"As soon as the frost is out of the ground, the foreman starts to surfacing, lining and gauging his track, and putting in ties. His force is increased, and if it is decided to do any heavy work, such as putting on ballast, an extra gang, commonly called the 'floating gang,' is put on, shifting from one section to another as the work requires.

"It is good policy to have floating gangs go over stone ballast track at least once every four years and bring the surface to a face.

"As the work progresses the roadmaster should be constantly alert as to the condition of track. He should ride over his division at least once every three days, on fast trains, taking particular notice of the riding of the track, and see that it is in perfect gauge, well lined and surfaced. The track may look to a section foreman to be in perfect surface, yet the roadmaster on the train will find low joints caused by the hammering of the train on a loose or battered joint which has pounded the

ballast from under the tie, thereby causing a low joint which, after the train has passed, will spring back and look to be in perfect surface.

"The roadmaster should also see that his track is well tied, and that each tie is well tamped up. He should pay attention to the waterways and ditches and see that they are cleaned out and kept free from all obstructions, so that his roadbed will be well drained. He should take frequent trips on his motor car or on foot over his division, examining the switches and frogs to see that they are in good condition. While on these trips, he can personally show his foreman how to do the finer work, such as lining the curve, etc."

Laying Cross-Ties.—"It is thought by some foremen," says Mr. P. W. Mosher, Roadmaster, Chicago Terminals C. & N. W. Ry., "that half an inch or an inch longer or shorter on either side of the rail does not materially matter. For example: We put 17 ties under a 30 foot rail, 8 of them 16 inches from the flange and 9 of them 15 inches from the flange of an 80 pound rail. Here we have a difference of 63 square inches, which gives us unequal bearings, and the track settles on one side more than on the other.

"The importance of ties being laid all with equal bearings should not," he says, "be overlooked."

Another roadmaster, writing of section foremen says: "The foreman who realizes that a train may be expected at all times; who lays out his work in advance; who appreciates the necessity of enough and no more ballast; who is an artist in surfacing, tamping and ditching and draining; who is mindful of storms, fences, old material, fires, weeds, brush and grass, who does not hesitate when emergency calls, is the one who will be a road-

master just as surely as his pay check comes every thirty days."

Regarding work gangs, another writes: "In the organization of work gangs, no matter for what purpose, it is a fact that the better organized the men are the better and more economically the work will be done. Each lot of men should be so assigned by their leader that when working in large gangs they can be gotten into line without delay when there is a change of work or other occasion for the use of thorough system, the foreman in charge always keeping the leaders instructed what to do and when to do it. Such instruction should be issued in time so that it cannot be said that 'haste made waste.'"

In bunching from ten to twenty gangs together for any purpose, each foreman should always be with his men to instruct and try to carry out the chief foreman's idea of the work, so that all gangs will act as one man.

Tamping Ties.—Regarding the question whether ties should be tamped throughout their entire length, Mr. Ole Hanson, Section Foreman, C. & N. W. says:

"I believe they should, so as to furnish a solid bearing, but not too solid in center so as to cause the track to rock or become center-bound. After the track is brought to surface and level, see that it is perfect to gauge and then line it up. In lining out kinks, stand three or four hundred feet from the lining gang so that a perfect direct line can be had. After lining see that all track is gauged, as spacing ties often makes small kinks, especially in ight rail and in this case, spikes should be reset, old holes plugged and bolts tightened up. The track should then be dressed up as the different kinds of material used would indicate. Gravel track should be dressed off by

filling center two inches above top of the center of tie to one inch below the base of the rail and two inches below the end and as far out as the amount of gravel will permit."

Caring for Track in Heavy Rains.—In Colorado where, owing to the mountainous character of the country heavy rains are followed by rushing torrents, Mr. J. Brown, Foreman of Sec. 55, C. & N. W. Ry., says:

"In case of heavy rainfall, track men should make their inspection right then and not wait until the rain is over, or perhaps to get a meal or possibly a few hours' sleep. I think this is the time the Company suffers most. I have known men that think because they have made their inspection right after the rainfall that the danger is all over. That is when I think there is the greatest danger. When the high grades and cuts are soaked with water and a slide is liable to take place at any time. Also in sloughs where muskrats have undermined track, it will settle then if at any time. All through these inspections the foreman should be the man as much as possible, as there is no time he is needed any worse, and I think for at least twenty-four hours after heavy and long rainfalls track should be inspected frequently. In cold weather I think track should be inspected first thing in the morning as broken rails are usually found between the hours of 4 and 9. Of course, in extreme cold weather an inspection in the afternoon should be made.

"I think a regular track inspection should be made during hot weather between the hours of 2 and 6 in the afternoon, as then is when the track is liable to get too tight and kink, and especially on double track where traffic is all one way.

"I usually have one man do my track inspection, as it is easier to make one man familiar with the weak points than a half dozen, and no matter what gang it is, there is always a choice, and I think the brightest man should be used for that purpose. In a period of eighteen years' service with this company as foreman I have never had a car wheel on the ground caused by condition of the track."

In case of floods and freshets likely to endanger the track, Mr. T. O. Tow, Section Foreman, writes:

"I call out the necessary help and go over and carefully examine track and bridges. I leave one man at each bridge in case of necessity, and at long bridges leave two men at night with the necessary signals to flag trains in case the track is not safe for traffic at the usual speed and have watchmen on day and night until the water goes down. This is very important.

"In extreme cold weather the man who inspects tracks must be provided with tools, a spike maul, a few railroad spikes and bolts, and a track wrench. In case of finding broken rail, spike on a pair of angle bars so it will be safe for traffic during the winter months. I leave angle bars along my section, putting them about one-half mile apart, so a man can find them if needed. I have fixed a number of broken rails this way myself, until I got help to fix them O. K. If spikes are in the way of angle bars, take a spike maul and knock the heads off. These tools and supplies can easily be carried by getting a cloth bag for spikes and bolts."

Use of Angle Bars.—"In winter time each section should have a pair of angle bars of proper size placed conveniently about every half mile and trackwalkers should know where to find them. A few spikes and

bolts should also be placed near at hand, and the track walker should carry a light or short handled spike hammer and wrench, so that he can put on bolts and drive spikes or knock off spike heads if in the way of angle bars.

"If you find you have several bent angle bars and only have five or ten pairs of new ones on hand, it is a good idea to put the bent ones into an old pile of ties and set fire to it, bending them back slightly when they have reached a fairly good heat; then raise the joint when putting them on the rails, and they will last nearly as long as a new bar. Turn the angle bars, too, and put them on the rails on opposite sides from that occupied formerly. This will give you a square shoulder on the slot and prevent the rail from creeping, much more than if it were not done.

"Whenever a low joint is being raised, tighten the bolts and spikes, for this will hold up the joint far longer than it would otherwise hold.

"A good way to prevent switches from lipping is to put a tie-rod on at the switch point and one at the heel, hooking them onto the flanges of the rails; then see that your switch-stand is not too badly worn to permit it to be loose at the points. If this is done it will greatly lessen derailments.

"Switches, frogs and guard-rails must receive special attention in track inspection and foremen should personally examine all connections in switches and see that cotters are in bolts and that all are snug and joints fit neatly, guard-rails securely fastened and bolts tight in frogs. Proper gauge must be maintained at all frogs and switches and watched closely."

Switches are of three styles, Stub, Split and Special

or Patented. The third style (comprising special and patented) being modification of or improvements upon the first two.

The Stub switch is here illustrated:

Fig. 68. STUB SWITCH.
Showing Head Blocks and Ground Throw for Moving Switch Rails.

The Split switch is the same in principle as the old English point switch used in England since 1830. The Clarke-Jeffery and Lorenz are of this style. See illustrations:

Fig. 69. Split Switch.

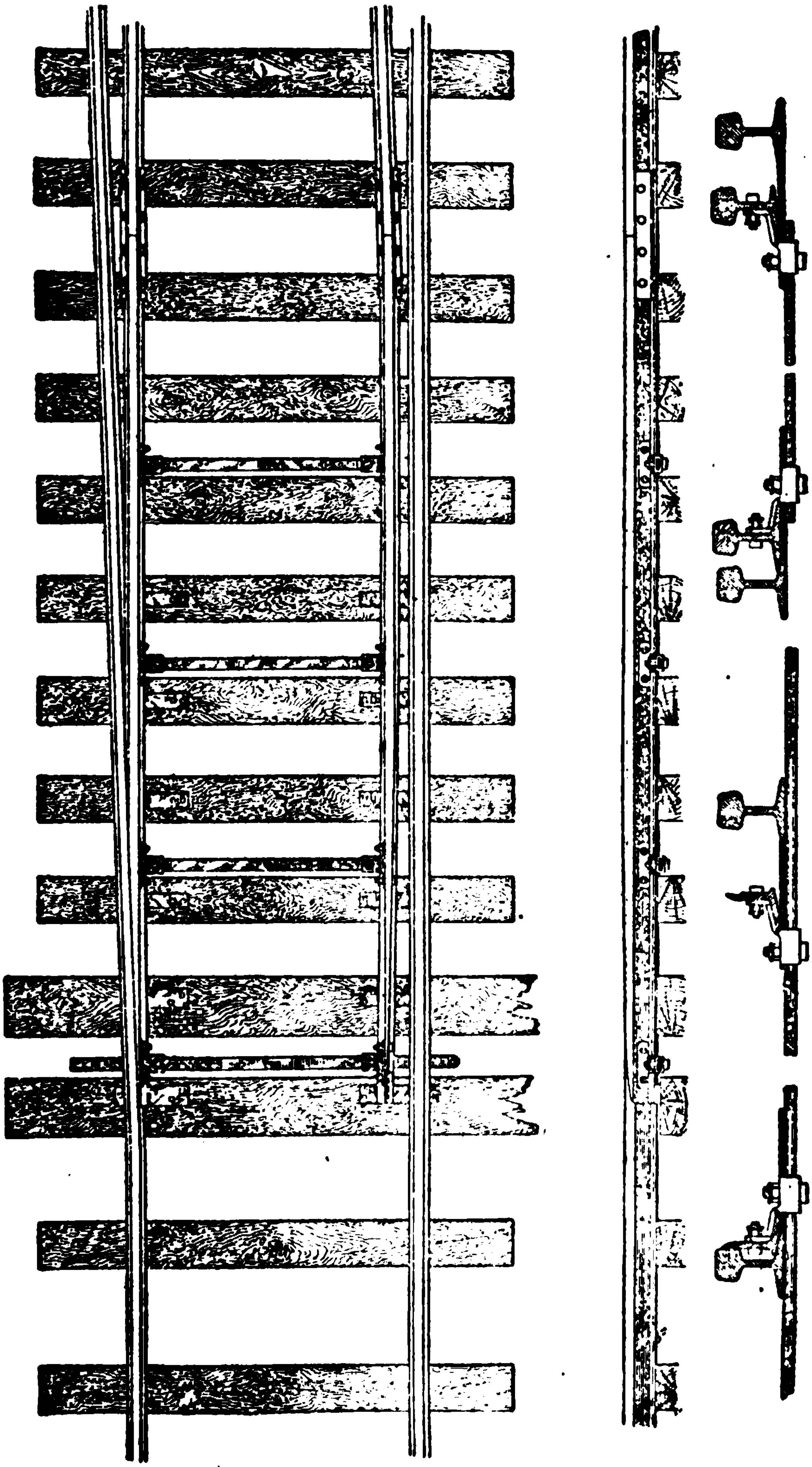


Fig. 70. Clarke Jeffrey Split Switch.

The improvements made by different makers are intended to take up the wear of the switch points, and so preserve the gauge true and also reduce the danger of the flanges of wheels running between the rail and switch point. This has been effected, in part, by a modification of the bridle rods. In the Transit Split Switch only one bridle rod is used, it being alongside the tie, hence it is not in the way when ties are tamped or when there is

Fig. 71. Lorenz Safety Split Switch

ice and snow. The Lorenz safety split switch has a heavy spring attached to a bridle rod at the point of the switch, strong enough to cause positive motion of the points, yet it permits a car to pass through when run from a siding into the switch, the spring then throwing the points back again to their proper position.

Switches of special design are mostly intended to give a continuous rail for the main line. There are various styles and makes including the MacPherson Improved Safety, The Wharton switch, The Duggan switch, etc.

The principal objection to the stub switch is that the

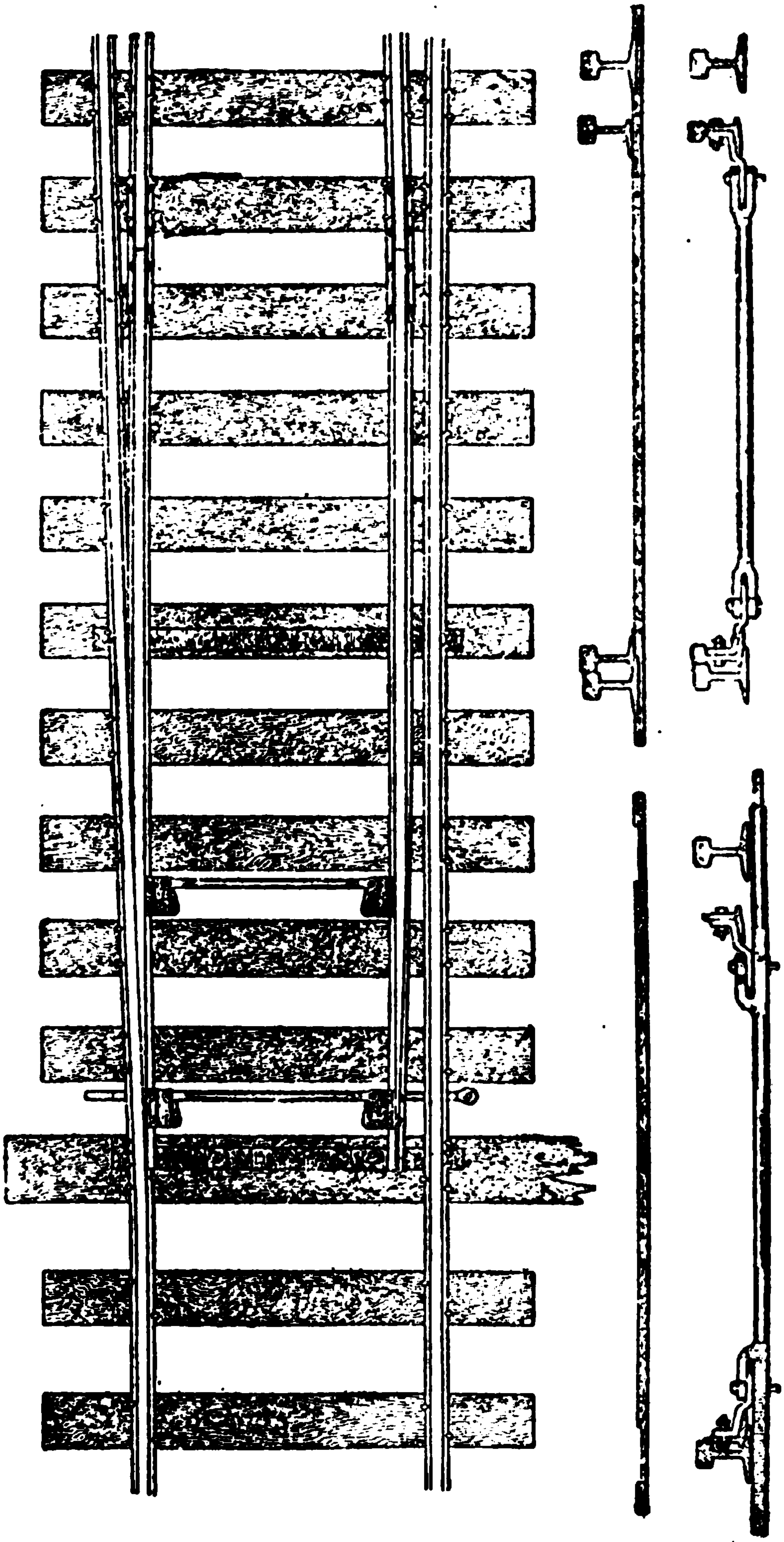


Fig. 72. Transit Split Switch.

Fig 73 Combination Slip Switch Crossing with Adjustable Tie Bars and Rigid Center Frogs, Operated from a Single Switch Stand with Rocker Shaft Connection.

pounding of the ends of the rails at the head block by the passing wheels causes the rails to bind at the head block when the expansion becomes great, and thus brings about the derailment of trains.

Their use should be confined to side tracks, but they are not to be recommended for use even there.

Frogs can be placed in three general classes: Rigid, spring rail and switch rail. The manufacturers of frogs and switches make about four styles of rigid frogs.

Rigid frogs are of two styles, in one the metal between the rails is in two pieces, in the other the two pieces are welded together where they meet at the point of the frog, making it stiffer and affording more support to the point. Some roads have styles which differ somewhat in detail and the various makers also differ in respect of style and detail.

Where the traffic on the main line tracks is heavy rigid frogs should not be used but where first cost makes it necessary they may be used on branches and in yards.

To prevent the pounding of the frog and to obtain a smooth riding main track spring rail frogs have been used to a considerable extent. It overcomes the weak point in the track caused by a rigid frog. The Eureka Spring Rail Frog illustrated here has all ends spliced solidly together as in a rigid frog. The hinge rail is attached to the main rail by a bolt hinge (see section I J); this allows the rail to move freely and prevents its creeping; it is attached to the movable part of the running rail by strong bolts passing through both rails and a wrought iron filling (see section E F). This makes this movable part strong throughout. Manufacturers have a number of other styles of spring rail frogs, and some roads have patterns of their own.

Spring rail frogs and movable points are being used in place of frogs to secure a smooth riding track.

The next illustration shows a movable point crossing, which is used instead of the frog by connecting the levers at the movable point with the switch stand. The Coughlin switch rail frog is designed to leave the main line track unbroken at the frog, there being no guard-rail or frog required for the main line. The principle of this spring rail frog is in use on the Lehigh Valley Railway and Western Maryland Railway. It can be

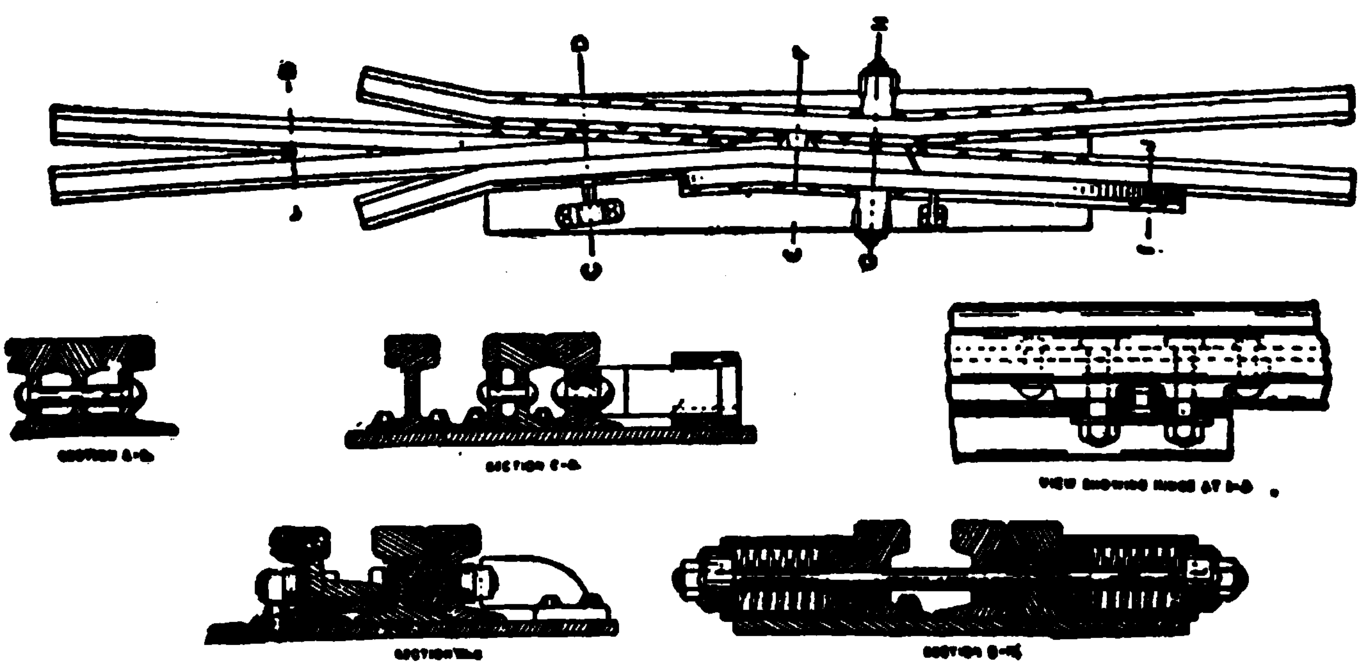


Fig. 74. "Eureka" Spring Rail Frog.

used with the split switch or Wharton points. The spring rail frog used with the MacPherson improved safety switch accomplishes the same object that the Coughlin switch rail frog does, except that a guard-rail is required on the main line track.

A crossing with very heavy angle bars having eight bolts, the bottom plates extending the length of the crossing (sometimes they are put under the corners) is shown in the following illustration:

Fig. 75 Movable Point Crossing.

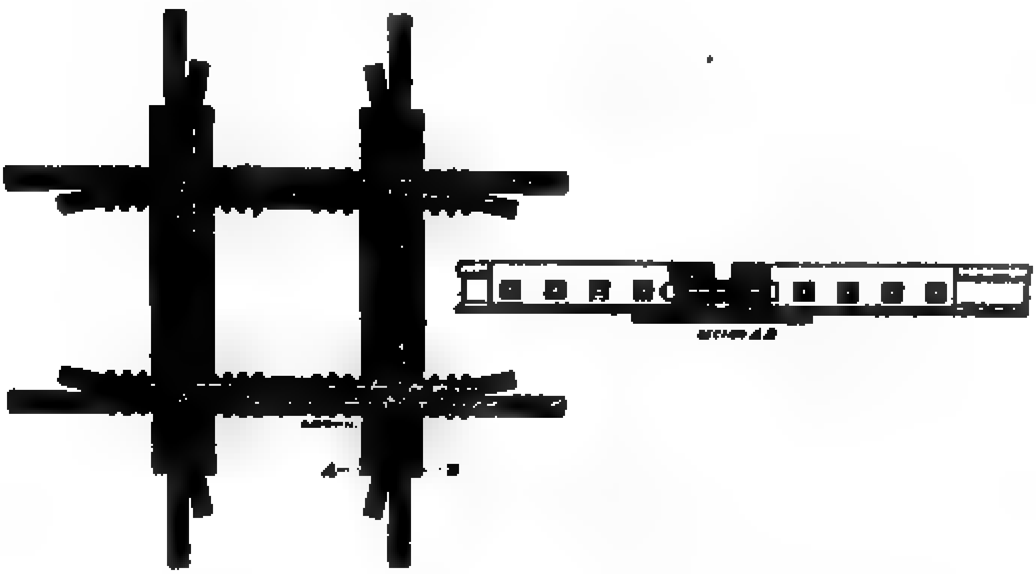


Fig. 76. Crossing Frogs with Extra Heavy Angle Irons.

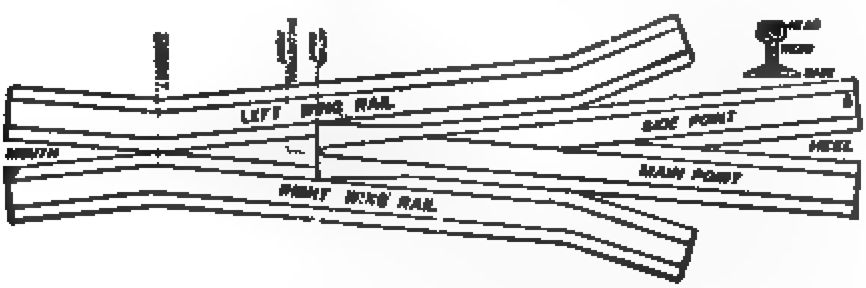


Fig. 77 RIGHT HAND FROG.

With the names of the different parts, the names would be the same with a left hand frog, only the main and side points would change positions. The main point connects with the main line rail and the side point with the side track rail.

Ordering frogs and switch points or tongues often leads to confusion on account of the section foreman or clerk not thoroughly understanding when they are right or left hand. A good rule is to stand at the head block and look towards the frog; if the frog is on the right hand it is a right hand frog, or if it is on the left hand, it is a left hand frog; the same rule applies to the switch points or tongues of a split switch and to the head blocks of a stub switch.

The different parts of a frog and their names are shown in the following illustration:

Instructions for measuring in order to take the angle of a frog and also an example are here shown:

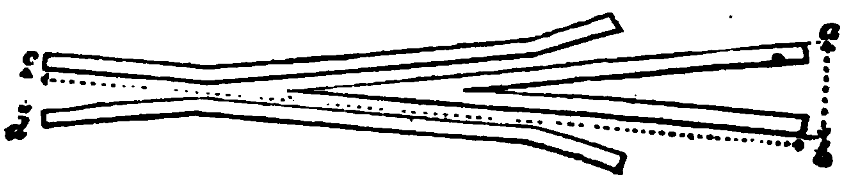


Fig. 78. TO TAKE THE ANGLE OF A FROG.

Measure A-B and C-D and add them together, then divide the distance B-C by their sum.

Example: Distance A-B=8″, C-D=4″, then 8+4=12. The distance B-C=72″, 72÷12=6 or No. 6 Frog.

Caution: In measuring be careful that all measurements are made on the running line.

A Three Way Split Switch is shown in the two illustrations which follow; one shows a view taken from the switch stand, the other shows the arrangement of the switch points.

The correct location of the frogs and rails from the headblocks to the frogs, and from the frogs to the sidings, when laying out side-tracks and yards, is a mathematical problem, and ought not to be done, as it sometimes is by calculations made by the section foreman's measurement through eye-sight alone.

Fig. 79.

The Elliott Frog and Switch Company furnish dimensions in detail for laying out switches where the switch point and frog angle are taken as tangent to the curve of the rail from the headblock to the frog.

The next illustration shows the construction of a "Combination Slip Switch Crossing."

Fig. 80. Arrangement of the Switch Points for a Three Throw Split Switch.

Fig. 81. Combination Slip Switch and Movable Center Points, Switches and Movable Center Points Operated by One Switch Stand.

Cross-overs enabling westbound or northbound trains to take sidings on south or east tracks and vice versa are necessary on double track roads.

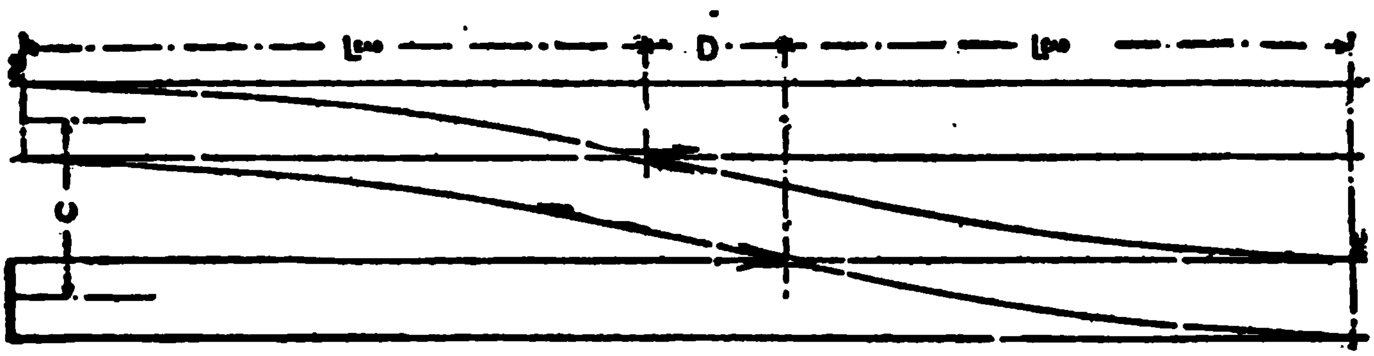


Fig. 82. Plan of a Cross Over.

"Care should be taken to place cross-overs so that trains will run through switches as shown in illustration and not against the point of the switch; this reduces the liability of accidents from derailment. Derailing switches should be placed on all side-tracks where the grade is such that cars are liable to run onto the main line. The safest construction is to place derailing switches at all sidings connected with the main line; high winds will cause light box cars to move on a side-track, or careless switching when a fast train is due has occasioned freight cars to run into a switch and caused accidents."

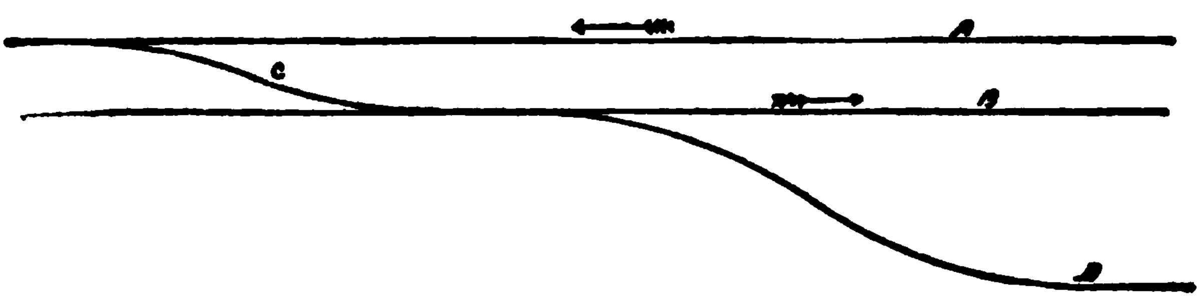


Fig. 83. Plan Illustrating the Use of a Cross Over or Switch Connecting the Two Main Line Tracks of a Double Track Road. C is the Cross Over Connecting Tracks A and B to enable a Train on Track A to Reach Siding D.

The next illustration illustrates a derailing switch operated from the switch stand which operates the main

line switch; when the switch is set for the main track the derailing switch is set to throw a moving car off the siding on the opposite side from the main line track. This switch is connected and operated by the movement of the main line switch. The cut shows the switch set for the main line and the derailing switch set to throw a car moving out of the siding from the track. When the switch is set for siding the derailing switch closes automatically.

Fig. 84. Derailing Switch Used to Prevent a Collision Between a Train on the Main Line and Cars Running off a Side Track onto the Main Line.

The following recommendations of the American Railway Engineering Maintenance of Way Association give in concise form practices for line and surface.

TRACK.

Maintenance of Line.

A. Tangents should be adjusted between summits, and between curves, throwing curves to meet tangents, or tangents to meet curves.

B. Basement curves recommended on—

All curves over one degree for speed of sixty miles per hour.

All curves over two degrees for speed of thirty miles per hour.

—to extend same distance out as curve elevation. For ordinary practice 100 feet per degree of curve.

Maintenance of Surface.

Elevation of curves: The inner rail should be maintained at grade, and for ordinary practice the maximum elevation of outer rail should not exceed 8 inches.

A. Spiking.

1—Use wooden gauge.

2—Gauge wherever spike is driven.

3—Start spike straight—face against rail—never straighten while driving.

4—Outside spikes of both rails on same side of tie. Inside spikes on opposite side.

B. Widening of gauge on curves. Committee make no recommendations.

C. Methods to prevent spreading track and canting rail on curves. Committee recommends—

1—For heavy traffic use tie plates on all curves.

2—For medium traffic use tie plates on curves over three degrees.

3—For light traffic double spike the outside rail.

4—Tie plates are recommended in preference to rail braces except for guard rails, stock rails and switches.

EASY RULES.

MIDDLE ORDINATE.

1—To find the degree of any curve: Find the middle ordinate of a chord 61 feet 4 inches. The number of inches in this M. O. is the degree of the curve.

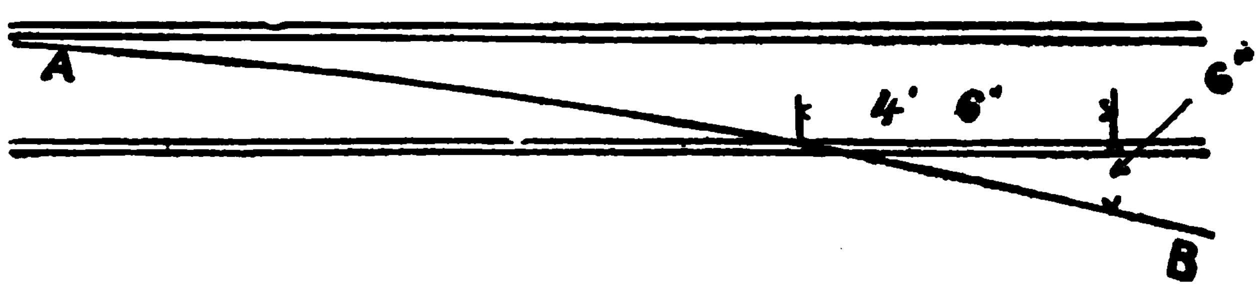
2—To find the middle ordinate of a 30-foot rail, divide the degree of the curve by 4. This is good up to 10 degrees.

3—To find the number of a frog:

Measure the distance in feet from the theoretical point of frog to where the gauge lines are 6 inches apart. Multiply this distance by 2. The result is the number of the frog.

TO FIND THE NUMBER OF A FROG FOR ANY TURNOUT.

Lay out line of lead, A. B. Mark where it crosses gauge line of rail. Measure the distance in feet to where this line is 6 inches from the gauge side of rail. Multiply this distance by 2. The result is the number of frog required.



For example: The distance shown in the cut is 4 feet 6 inches. Number of frog required is No. 9.

TABLE OF TIMBER

DRY

NAME	Specific Gravity	Wt. per Cu. Ft.	Wt. per 1000 Ft. B. M.	Ft. B. M. per Net Ton
Ash..............	.61	38	3166	632
Cherry............	.67	42	3500	571
Chestnut..........	.66	41	3417	585
Cork..............	.25	15.6	....	...
Elm...............	.56	35	2916	686
Hemlock...........	.40	25	2083	960
Hickory...........	.85	53	4416	453
Mahogany..........	.85	53	4416	453
Maple.............	.79	49	4166	480
Oak, White........	.77	48	4000	500
Pine, White.......	.40	25	2083	960
Yellow Southern......	.72	45	3750	533
Sycamore..........	.59	37	3083	650
Spruce............	.40	25	2083	960
Walnut............	.61	38	3166	632

Green timber weighs from 20% to 40% more.

TABLE OF WEIGHTS

FUELS

KIND	BROKEN		SOLID	
	Wt. per Cu. Ft.	Cu. Ft. per Ton 2000 lbs.	Specific Gravity	Wt. per Cu. Ft.
Coal, anthracite	57	35	1.5	93.5
Coal, bituminous, lp.	50	40	1.35	84
Coal, bituminous, sm.	54	37	....	....
Coke, hard	27	74	....	32
Coke, soft.........	20	100	....	25
Charcoal..........	15	135	....	15 to 30
Peat, pressed.......	20	100	....	20 to 30
Oil, fuel..........	54.8	36.5	.878	54.8

TABLE OF FEET B. M.

Per Lineal Foot for Various Widths and Thicknesses of Timber

TABLES OF WEIGHTS

METALS

BUILDING MATERIAL

TABLE

Showing the Number of Feet, Board Measure Contained in a Piece of Joist, Scantling or Timber

SECTION III.

BRIDGES AND BUILDINGS.

In a lecture which he delivered before the Transportation Class, Institute of Pennsylvania Railroad Department, Y. M. C. A., Philadelphia, regarding bridges, Mr. H. R. Leonard, Engineer of Bridges, Pennsylvania Railroad, said:

The definition of bridge as any structure which spans a body of water, or a valley, road, or the like, and affords passage or conveyance, would place this class of structure among the earliest of engineering achievements. The history of bridge building, however, may be divided into two epochs, which can be aptly termed the mechanical and the scientific.

Prior to about the middle of the last century bridges were built (that is, so far as any records show) by engineers or mechanics who were obliged to rely wholly on their judgment or experience in proportioning the various parts of their structures; the familiar stone-arch bridge was probably the earliest form used, and records, ruins, and still-existing structures combine to show to what proficiency the art was brought.

A bridge was built across the Tagus at Alcantara, Spain, about A. D. 104, consisting of six arches of varying spans, having a total length of 670 feet, built of granite blocks laid without cement, and continued in use until 1809, when it was partially destroyed by English troops. Seventeen hundred years of time and travel is certainly an endorsement of the skill of its builders.

Wooden construction, owing to the destructibility of the material, cannot be traced back as far as the stone, but some remarkable structures were built in the latter part of the eighteenth and early part of the nineteenth centuries, spans of 368 feet and 340 feet, the latter across the Schuylkill at Fairmount having been completed and put in service. Such spans would be considered long even in steel construction.

Great ingenuity was displayed in framing some of these structures, and bridges are in existence today having absolutely no metal in their construction other than the spikes in floor plank and nails in the weatherboarding. Many forms of wooden bridges were developed, but science and economical conditions have practically eliminated all but one type, known as the "Howe truss," of which we have quite a number on this system.

The scientific epoch in bridge building can be said to date from 1847, when Squire Whipple published a book under the title "A Work on Bridge Building." In this publication was contained the first scientific analysis of the various stresses in a truss bridge. The circulation of the book was small, and it was some years before its influence was seen or felt in engineering circles.

In 1851 Mr. Herman Haupt, who had extensive experience in building wooden railroad bridges, published a work on "The General Theory of Bridge Construction." This was produced independently of Mr. Whipple's work, as his preface states: "If any work exists containing an exposition of a theory sufficient to account generally for the various phenomena observed in the mutual action of the parts of trussed combinations of wood or metals, the author has neither seen nor heard of it."

These two works mark the first step in the development of our modern structures.

The rapid expansion of the railroad systems of the country is largely responsible for the development of the American railroad bridge; and many engineers turned their attention to this branch of engineering, but rather as contractors than as engineers. Many different types of bridges and parts of bridges were patented, some having considerable merit and others none at all.

Up to about 1874 the designing of bridges was almost exclusively done by the contracting companies, each having its own peculiar style of bridge. This custom led to the development of economical bridges at first cost, which, in the earlier stages of railroad construction, was a considerable factor. But as traffic grew it was soon seen that first cost was not the only item to be considered, and the railroads began to devote some of their engineering talent to this branch. I would say at this time that the Pennsylvania Railroad was among the first, if not the first, to appoint an Engineer of bridges, which was done in 1865, Mr. Joseph M. Wilson being placed in charge of the department at that time. Maintenance was seen to be of considerable import, and more attention was paid to details with a view to producing a lasting bridge than to producing a bridge which could be sold for the least amount of money. The materials used in construction were studied more closely, and still more rapid progress was made, until at this date, while we do not claim perfection, we may claim that we have advanced fairly well toward that goal.

Metal bridges were built on the Pennsylvania Railroad as early as 1851, of spans varying from 65 to 110 feet, on what is now the Pittsburgh Division. These

were partly of cast iron; and it goes without saying that they have since been replaced.

The nature of the country to be traversed in building our railroads led to the development of truss bridges, differing completely in make-up and detail from the bridges in use in England and on the Continent. Foreign-built bridges were put together with rivets at all their joints, and even to this date are assembled in the shops to insure accurate fit. But the necessity for speed both in manufacture and erection prompted our engineers to adopt what is called the Pin-connected Truss, the great number of small rivets at each joint being replaced with one large pin or bolt. The parts could be manufactured and the pin holes so accurately bored in the shops that further assembling was unnecessary until the work was put together at its final site. And the substitution of the pin for the rivets enabled bridge erectors to complete the work on the ground in much less time than is required for the erection of the so-called riveted bridge. As the bridge in process of erection is carried on light false work in rivers that are liable to sudden rises or floods, the time saved at this stage was of great importance. The adoption of the pin system is the one point where American practice differs from that of our foreign neighbors.

About two per cent of American railroad mileage is carried on bridges. This seems small when spoken of as a percentage, but when considering the total mileage, is considerable. On the Pennsylvania System we have a total of 146.38 miles carried on bridges. This is under the general average, we having 1.85 per cent on a total mileage of running tracks of 7,700 miles on the lines east of Pittsburgh and Erie. This is carried on 4,005 bridges,

822 stone or brick, 2,368 of iron or steel, and 815 wooden structures. This number seems large, but included in this list are many small bridges for cattle-passes and road-crossings. But as an offset to these smaller bridges there are many bridges of considerable length, notably the Rockville bridge, the Shocks bridge and the Havre-de-Grace bridge over the Susquehanna river, and the bridge over the Delaware at Philadelphia, all of several thousand feet in length. The large number (815) of wooden bridges includes a great many wooden trestles or pile bridges, with which you are no doubt familiar; although we still have some wooden truss bridges on the system which are gradually being replaced. In addition to the number of bridges carrying our tracks, we have something over 900 overhead bridges carrying highways, most of which have been built by the railroad company.

The standard bridge of the Pennsylvania Railroad (if we may call it so) is the masonry arch, and when given the conditions for the successful building of the same, should always be the structure adopted. The essential conditions for the successful building of the masonry arch are good foundations and plenty of room, so that we may have ample rise of arch. Once properly built the cost of maintenance of the masonry arch is reduced to almost nothing; and the standard track construction can be carried over it the same as on the solid earth.

There are, and always will be, locations from which the masonry arch will be debarred, and at these points steel bridges must be built. And these are built in various styles, as follows, viz.:

For extremely short openings, say up to twenty-one feet, rolled beams.

For moderate length of spans, say up to 120 feet, plate girders.

From 120 feet to about 200 feet, riveted truss bridges.

From 200 feet upwards, pin-connected truss bridges.

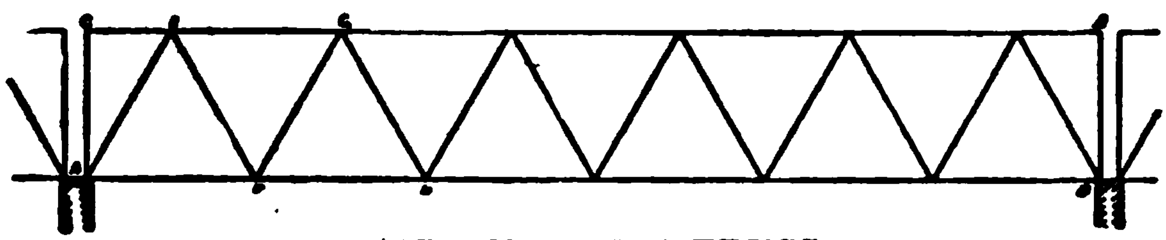
First we will describe a truss. A truss consists of any number of parts, dependent of course on its size, but in general division consisting of chords, flanges, and web members. The chords are longitudinal, and the web members connect the upper and lower chords both vertically and diagonally, and divide the entire truss into a series of triangles. The triangle cannot change its shape, and as it is necessary to preserve the integrity of the whole, the truss must be so divided. The connection of the web members to the chords determines whether they are pin-connected or riveted trusses.

Perspective View of Through Plate Girder Bridge.

Plate girders differ from truss bridges inasmuch as for the separate web members there is substituted a solid plate or web, the chords still being there but termed flanges, and are rigidly riveted throughout their entire length to the web plate.

The I-beams mentioned are of the same general form as the plate girders, but are commercially rolled in all our large mills to a form approximating the girder. No further mention need be made of I-beams.

Plate girders are made in two styles, termed deck and half through. The deck bridge carries the track on its upper flange, while the half through has a solid floor system consisting of smaller girders resting on or framed just above the lower flange. This type is used a great deal for street and other crossings where we have a limited amount of room between the rail and the road or stream to be crossed. Truss bridges are termed either deck or through for the same reasons.



DECK WARREN TRUSS.

A B is the lower chord.
C D is the upper chord to which the bridge floor is attached.
A C and B D are the end posts.
A E, E F, F G, G H, etc., are the oblique members.

All our bridge structures are designed to carry the weight of the track and the weight of the structure itself, which combined weight is termed the dead or static load; and the weight of two locomotives and the following train, which is termed the live load. The earlier bridges were designed to carry as a live load one ton per lineal foot. Our first printed specification, issued in 1883, called for a live load of two eighty-six-ton locomotives followed by a train load of one and a half tons per foot. Our specification of 1887 called for two locomotives each weighing 100 tons, followed by two tons per lineal foot of train. In 1897 the weight of locomotives was increased to 125 tons, and in 1901 the weight of our live loading was further increased to 158½-ton lo-

comotives, followed by a train load of two and one-half tons per lineal foot; while our present practice is to meet a load of two locomotives weighing 187 tons each and a train load of two and one-half tons per lineal foot. The weight of engines specified in 1883—that is, eighty-six tons—was a little in excess of that of the actual locomotive of that date; the actual weight of our H-6-A locomotive now in use is 168½ tons. So that the motive power in a period of twenty years has increased in weight nearly 100 per cent.

The question has often been raised as to what is the life of a metal bridge. It is almost impossible to answer this question, as no properly designed railroad bridge has carried the load for which it was designed long enough to wear out. The most of our renewals are due, not to the bridges wearing out, but to the fact of their having to carry such greatly increased loads. The present load we are using in designing you will note is somewhat heavier than our H-6-A locomotive, which is the heaviest now in use on the system. This excess we hope will provide against any further increase in weight.

For most of our proposed bridges the locations are such that we know at a glance what class of bridge is required. But where a wide stream is to be crossed the character of the bridge must be carefully thought out so that an economical and effectual span may be adopted. The cost of the superstructure of a bridge—that is, the steel portion—varies almost as the square of the span; while the cost of the substructure—that is, the piers and abutments—varies very nearly as the length of the span; so that to obtain the proper relation both the substructure and the superstructure must be carefully estimated. Take for example the new bridge now building

at Havre-de-Grace. On the north side of the river foundations were deep and expensive; while on the south side of the river, rock was quite near the surface of the water. After careful study, spans of 260 feet center to center of piers were adopted for the north side, and spans 200 feet center to center of piers for the south side.

After determining the length of span and character of bridge proposed, the stresses in all its members are calculated for dead and live loads. Then owing to the dynamic effect of the swiftly moving live load we add a certain percentage to same, which we term impact. This amount of added stress is to cover not only the dynamic effect, but also the jars and jolts from imperfect track, flat wheels and imperfectly balanced locomotives. Having calculated the stresses occurring in all members of the various kinds, the various parts are proportioned to resist same. Many tests of material have been made which enable us to determine to what extent we may strain the steel of which these parts are composed. A general plan, on which is indicated the stresses and size of members, is prepared, which is termed the strain sheet. The practice of the Pennsylvania Railroad for a good many years in contracting for their bridges has been to buy same by the pound. This method removes from the contractor any temptation to skimp in details or connections, and enables the railroad company to determine just what it wants in regard to these details without continually wrangling with the contractors, contracts being based on a pound price on the strain sheet above referred to, standard specifications and the general details usually furnished the contractor.

The standard specifications referred to give as minute directions as possible covering the entire structure, loads,

allowable stresses on steel for all the different members; also such general directions as to details as can be made to cover the general practice. It also specifies the quality of steel and character of workmanship, and defines the tests that all this material must fulfil before acceptance. These specifications are drawn with the utmost care, but it is impossible to cover all points. Mr. Theodore Cooper, one of the most eminent bridge engineers in the country, has published a general form of specification, and has printed on the cover of same a sentence which is probably more important than any contained between the covers of his or any other specifications, and reads as follows: "The most perfect system of rules to insure success must be interpreted upon the broad grounds of professional intelligence and common sense."

After the work is placed, so-called shop drawings are made, which locate accurately every hole and connecting rivet for the entire work. These shop drawings must be carefully scanned, as the strength of the weakest part measures the strength of the whole; and no work is manufactured until such shop drawings have been checked and approved. During the progress of manufacture a careful inspection is made of both raw material and finished work; and this inspection is maintained up to the time that the bridge is erected and ready for travel. I need say nothing further in regard to inspection, as this is the subject-matter of another talk.

The different styles of bridges now in use have been already referred to; there are numerous other types of construction which the length of span and character of location render more adaptable than the styles referred to—notably the metal arch, the suspension bridge, or the cantilever truss. These three types can be built in much

longer spans than the simple truss, and can also be erected without much false work. Metal arches and the cantilever bridge have been built over the Niagara gorge where no false work could be placed. Suspension bridges can also be erected without false work, as some of you have doubtless seen in the work over the East River at

Cantilever Bridge at Mingo, O. Pittsburg-Wabash Extension.

New York. Simple truss bridges have been built to the maximum span, I think, of 550 feet. The East River suspension bridge has a span about 1,575 feet, and is the maximum for that type. A cantilever bridge has been built with a span of 1,700 feet over the Firth in Scotland, and a cantilever bridge of 1,800-foot span is now being built over the Saint Lawrence at Quebec.

In closing I would like to say that the same care which is used in designing and building railroad bridges should be exercised in maintaining same. Inequalities of track, not only on the bridge but on the approaches to same, will cause swinging and weaving of locomotives and cars, which should be avoided. And painting, it should be remembered, is primarily for the preservation of the structure rather than for appearance.

I have endeavored to give you a general idea of the subject, and have purposely avoided going into any details, as the subject is one that can be mastered completely, if at all, onlv after years of experience and careful study.

The questions and answers which follow were evolved during a discussion which followed Mr. Leonard's lecture:

QUESTIONS AND ANSWERS ON BRIDGES.

Q. What are the usual imperfections in modern bridges?

A. There should be no imperfections in a modern bridge, within the limits of our knowledge, provided that the designing, checking and inspection of the work are in competent hands.

Q. What is the chief advantage of steel bridges?

A. They can be built in longer spans than masonry arches, and where there is doubtful foundation or limited room.

Q. What is a cantilever bridge?

A. A cantilever bridge usually consists of three clear spans resting primarily on two piers and anchored to

two abutments. The span between piers and abutments is called the anchor arm, and projecting into the central span from each pier are portions which are called the cantilever arms. At the centre of the bridge and between the ends of the cantilever arms is a portion of the bridge called the suspended span.

Q. What rule determines the distance between the anchored ends of the bridge and the pier?

A. No fixed rule.

Q. What is false work?

A. Temporary scaffolding for erecting bridges.

Q. What is reinforced concrete work?

A. Cement concrete in which is bedded steel or iron rods, or other shapes for strengthening purposes.

Q. Is that better than stone for foundations?

A. Reinforced concrete is not used for foundation work.

Q. Which makes a stronger joint, one with heated rivets or cold rivets?

A. Rivets driven hot.

Q. Which is cheaper, steel spans or stone arches, at first cost?

A. This is a broad question. Given the conditions for building stone arches, at present price of steel, arches would be cheaper.

Q. What is the object of putting up half of stone arch bridge at a time?

A. This is never done except in cases of four-track bridges, and then only to prevent interruption of travel on the existing lines, if the completion of the four-track width would interfere with same.

Q. In steel spans, is provision made for expansion?

A. Always.

Q. Is the superiority of American bridge-builders demonstrated?

A. This is a question that would be better answered by a neutral. However, a number of English bridge-builders have imported American managers.

Q. Does it happen that one side of a stone arch bridge settles?

A. All structures are liable to slight settlements.

Q. Is the percentage of bridge mileage increasing?

A. Yes, owing to elevation of our tracks through towns and cities.

Q. What governs choice of style of bridges?

A. Local conditions.

Q. Is cast iron used in the construction of bridges?

A. Only in minor details.

Q. Is the concrete foundation better than the stone foundation?

A. There is a difference of opinion on this point; but the drift is towards concrete foundation.

Q. What is the factor of safety?

A. The ratio between the load for which the work is designed and the load which would cause its destruction.

Q. What is the limit of elasticity of steel?

A. The amount of stress per square inch which steel can be subjected to without causing a permanent distortion, and under which the metal will reassume its original dimensions when relieved of load.

Q. How is it determined when a bridge is too weak to stand the travel?

A. By calculation of the stresses in the structure, and further, by its action under travel.

Q. Who makes the shop drawings for a bridge?

A. The contractor's draughtsmen.

Q. Who checks the shop drawings?

A. The railroad.

Q. Does this free the builder from responsibility?

A. It does not.

Q. About how much a pound does a bridge cost?

A. Prices vary considerable. At present about 4 cents per pound in place.

Q. How was the span put in over the Schuylkill River without loss of time?

A. False work equal to the width of three bridges was placed under the existing structure, and the new bridge built on one side and the track placed on same complete. Under the new and old bridges were placed rollers, and when the work was complete the change was made by rolling out the old bridge, and by the same operation putting the new one in place and connecting the rails.

BRIDGE AND TRESTLE CONSTRUCTION NOTES.

The construction of wooden trestle bridges is a subject of too much detail to admit of comprehensive treatment within the scope of this volume. The notes which follow are chiefly extracts from a very exhaustive work by Mr. Wolcott C. Foster upon the subject of constructing wooden trestle bridges, according to present practice on American railroads. By his kind permission and through the courtesy of his publishers, Messrs. John Wiley & Sons, the quotations referred to are made.

The whole subject of pile drivers, pile driving, trestle and bridge construction is covered in a comprehensive manner and the details given very fully by Mr. Foster, who in relation to pile drivers states that:

While there are a great many forms and styles of pile-driving apparatus, there are but three principal methods of sinking piles in general use. These are:

1st. To force the piles into the ground by allowing a heavy weight to fall upon them when in an upright position, or by striking heavy blows by some means upon their heads or tops.

2nd. To sink the piles by means of a jet of water.

3rd. To screw the piles (which are either of iron or else have a special shoe) into the ground.

As the first of the methods is the one most extensively used, we may say almost universally, and the one most generally applicable to trestle building, we will confine ourselves strictly to a description of several different

forms of apparatus for accomplishing the desired end by this means.

The particular kind of machine to be used will depend upon the special conditions surrounding the case.

In very rough and bare country the simpler and lighter the machines, consistent with the requirements of the work, the better. Sometimes merely a pair of leads with the necessary stays or back-bracing to give them the required stiffness, a common hoisting machine (usually horse power in such a case as this), with the hammer, ropes and locks, are all that are carried from place to place. Everything is made as simple as possible, and so that it can be taken apart for transportation. Sometimes the apparatus is mounted upon wheels, so that it may be folded down and drawn around by a team of horses. When the scene of action is reached the leads are merely raised up. This lifts the wheels off the ground. The base is then lashed to a couple of 12-inch logs, and as soon as the hoister is put in position and the tackle arranged, everything is ready for the commencement of the driving.

Where transportation is not too difficult, it is preferable to use a more complete driver. A steam-boiler and hoister is substituted for the horsepower one. With this arrangement the driving proceeds more rapidly and at less cost.

When many piles have to be driven in navigable waters, the driver is mounted on a scow.

Continuing, relative to this subject, he says: In double-tracking a single-track road, or in repairing trestles in use, a form of driver mounted on a flat-car is found to be very convenient and economical. Figures 84A, 84B, 84C to 84D show the details of one of the

latest designs for a driver of this kind (taken from the Railway Review, October 25 and November 8, 1890).

It was constructed by the Missouri Pacific Railway, with the purpose of obtaining a machine which could work effectively on piles at a further distance from the roadbed than usual. The design was worked out jointly by the Bridge and Building Department and the Car Department.

Figure 84B shows the framing of the upper deck of the pile driver and of the cab. It will be noticed that the main timbers are very long—57 ft. 8 in., and are 5 x12½ inches in thickness. The side sills are 6⅞x12½ inches, and 43 feet long. From the centre of the track on which the platform revolves to the center of the lead is a distance of 33 feet and in order to reach work that is located 16 feet to one side of the center of the track the driver must swing to an angle of about 30 degrees from the track. The upper platform travels upon three circular tracks. The first is a complete circle, having a diameter of nearly nine feet, and as the car is 9 feet wide and the upper platform 10 feet, this track is fixed. The next circle has a diameter of 13 feet 3 inches, and is composed of four pieces of rail of the ordinary section, two of which are firmly secured to the car platform, while the other two pieces overhang the sides of the car and are removed while the pile driver is in transit. When in use they are supported in position by two wrought-iron swing-brackets fastened to the outside face of each side-sill, and are also secured to fixed sections by fish-plates. The third circular track has a radius of 14 feet 5 inches, and is a bar of iron 4x1 inch. This track is not carried beyond the sides of the car. The wheels which bear upon the two smaller circles are attached di-

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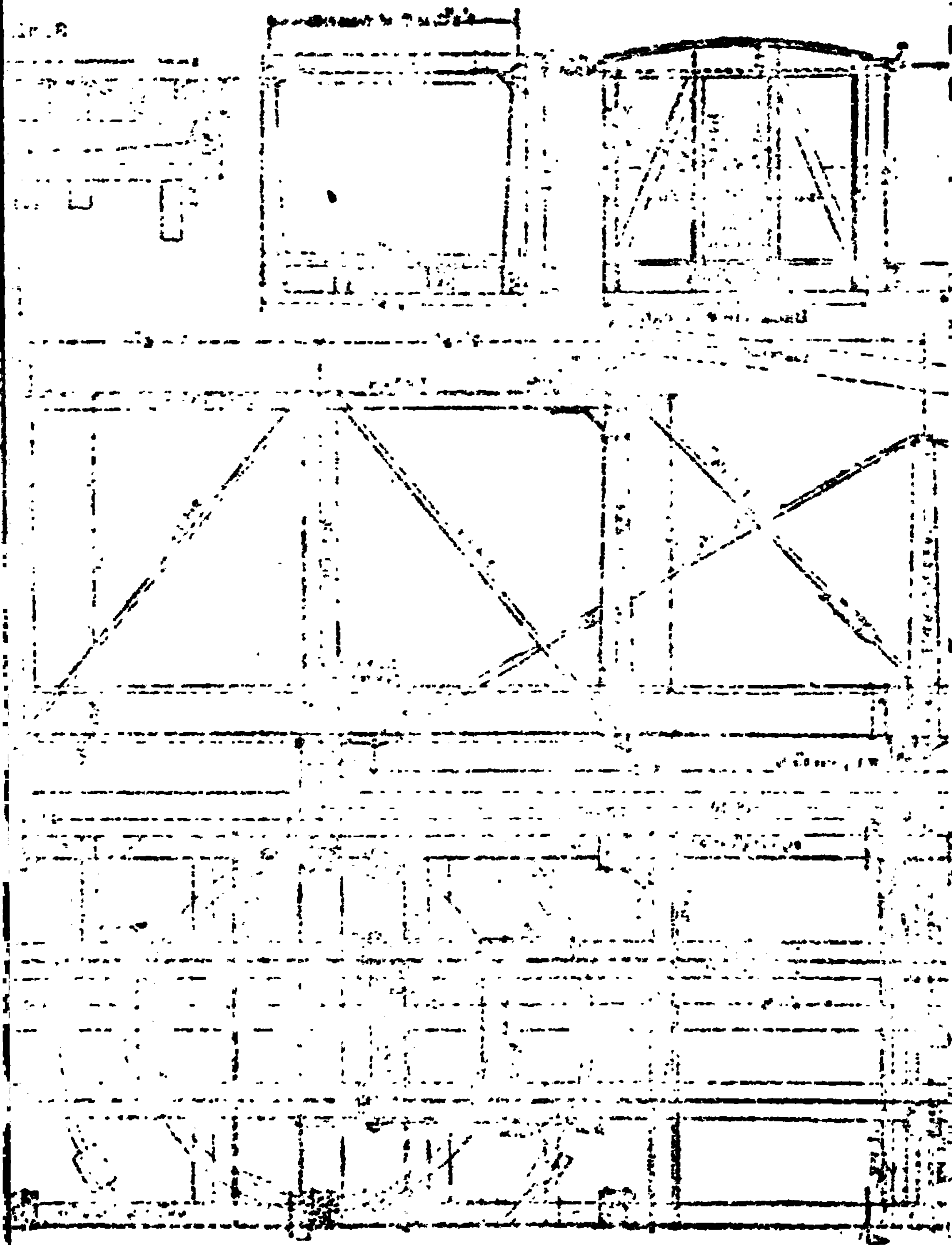

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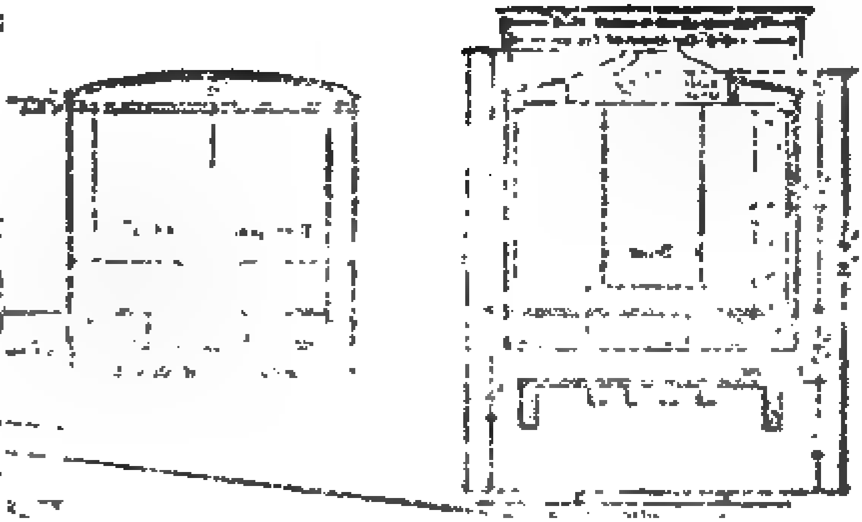

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rectly to a heavy flooring on the under side of the platform, and as far as possible they are placed in the vicinity of a longitudinal sill, so as to give them as solid a bearing as possible. The rollers which bear on the outer one of the three tracks are secured to the under side of a heavy transverse bolster, which is composed of three pieces of wood with three wrought iron plates, 6x⅞ inches in section intervening between them, the bolster being 6x10½ inches in section. The bolster at the center-pin is wood 12 inches wide and 9 inches deep, and is trussed by two rods each an inch in diameter.

Fig. 84C. Car Pile Driver, Missouri Pacific Ry.

The construction of the leads will be best understood by a reference to Fig. 84A. The leads are 36 feet long, and are hinged to a heavy triangular frame work, a detail of which is shown in Fig. 84B. A sole-plate 10x⅝ inches in section is secured to the upper face of the longitudinal sills which support the beam. The hinge-frame is secured to this plate, and consists of pieces 6x⅞ inches reinforced by angle-irons. The inner faces of the leads are protected by steel channel irons extending up from the bottom end for a distance of 26 feet. These

afford a good bearing for the hammer, which is planed out to fit them.

The car upon which the pile driver is carried is shown in Fig. 84D. It is an exceedingly heavy car, as will be seen from the inspection of the drawing. It is 30 feet long and 9 feet wide and very strongly trussed. The rack for moving the upper deck is seen in this view, and requires no explanation. When the car is in transit, 4 jack-screws, one at each corner of the car, are adjusted against suitable sockets on the under side of the upper deck so as to steady the entire superstructure. At the same time the upper deck is prevented from swinging out of a longitudinal position by means of suitable hooks attached to the upper deck, which engage eye-bolts in the ends of the car. When the pile-driver is at work these jack-screws are released and the heavy screws seen extending down through the floor of the car are made to bear upon the truck frames. This prevents any undue strain on the truck springs, and also any unsteadiness which might be caused from their elasticity."

The hammer weighs 2,397 pounds, and is operated by a Lidgerwood hoisting engine. As will be seen from the illustrations, the upper platform of the pile driver is so long in comparison with the car which carries it that a flat car at each end is necessary for its transportation. One of these cars is constructed for the purpose, and carries a supply of water and coal, and any other material which may be necessary. This is attached at the cab end of the pile-driver, and the one at the other end is a common flat-car.

The matter of foundations is gone into by Mr. Foster, with thoroughness of detail, who says further, in regard to grillage and crib foundations:

Fig. 84D. Car Pile Driver, Missouri Pacific Ry (Details of Car.)

Fig. 84E. Crib Foundation

On some of the branches from the Cripple Creek extension of the Norfolk and Western Railroad, crib foundations are used for the trestles. These cribs are formed by piling logs on top of each other, notching them where they cross, and then filling up the interior with stones. Fig. 84E.

Marking Piles for Cutting off.

They are built pyramidal in form, and are suitable for side-hill work where the slope is not too great, though their use is not by any means limited to this kind of ground, as they form a good foundation on the level. When on a side-hill the ground beneath them is excavated in steps, and the cribs are built up level so as not to necessitate the breaking of the sill. The logs composing the crib should be at least ten inches in diameter at the smallest place, and it is better if they are not under foot.

In regard to driving piles, which is treated at great length, he says, concerning "marking piles for cutting off":

As soon as the pile-driving has advanced a short distance, the preparation of the top of the piles for the reception of the cap is begun. The elevation of the top

Fig. 84F. Grillage Foundation.

of the pile is marked by a line on the face of one or two piles in each bent by the engineer.

A narrow plank having a straight upper edge, and long enough to extend entirely across the bent, is then nailed on each side of the piles (Fig. 84F) and the top cut off level or cut in far enough to form the tenon. A cross-cut saw worked by two men is very convenient for this work.

Fig. 84G. Pile Tenon and Trenail

There are several ways of fastening the caps to the piles—by mortise and tenon, by drift-bolts, or by dowels. For solid caps, a tenon 3 inches thick, 8 inches wide and 5 inches long is a very good size. The edges around the top of the tenon should be chamfered (Fig. 84G). When tenons are employed, it is customary to use wooden pins (treenails) for fastening the parts together. The pins may be of any tough hard wood. White oak and locust answer all the requirements very well. They ought to be from 1 to 1½ inches in diameter, and slightly

tapered—say 1/8 to 1/4 of an inch (Fig. 84G). The hole in the tenon should be somewhat nearer the top of the pile than that in the cap is to the edge, so that the pin when driven in will draw the two parts tightly together. Bolts 3/4 of an inch in diameter have been sometimes used in place of pins, but are not as desirable; in fact, their use should be discouraged. When drift dowels are employed the top of the pile is cut off square. Dowels frequently extend through the cap; generally one, sometimes two, drift-bolts or dowels per mile are used; one is amply sufficient.

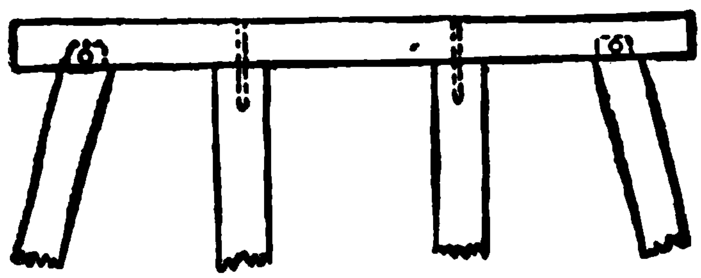


Fig. 84H. Fastening Cap to Piles.

Sometimes a mortise-and-tenon joint is employed for the outer piles, with the inner piles cut off square, and drift bolted as shown in Fig. 84H.

There is still another method of fastening the caps to the piles, which is rapidly becoming the general practice, which is by the use of split-caps. Instead of a single piece of timber for the cap, two pieces, each half the size, are employed. For instance, a single 12x12 inch stick is replaced by two 6x12 inch sticks. A tongue or tenon about 3 inches thick and the full width of the pile is formed on its top, and one of these pieces placed on either side and held in place by one, or better, two 3/4 or 1 inch. bolts passed through at each pile. The sticks should not be notched and they should rest evenly on the edges

formed on top of the piles. This form of cap is claimed to have many advantages, among which may be mentioned:

1st. On account of smaller size, better timber may be obtained at less cost.

2nd. Repairs may be made with ease and great economy in time and labor.

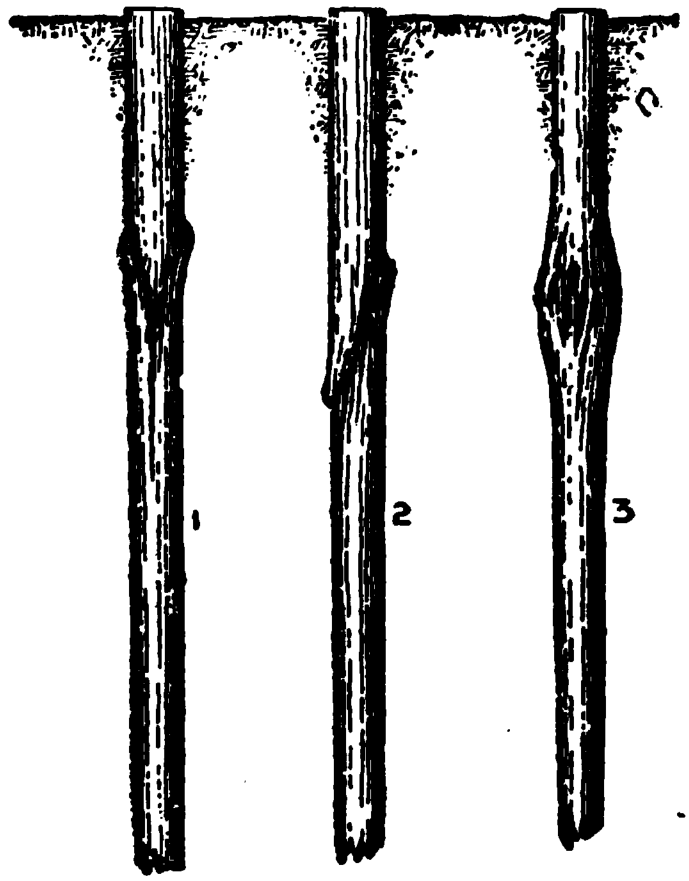
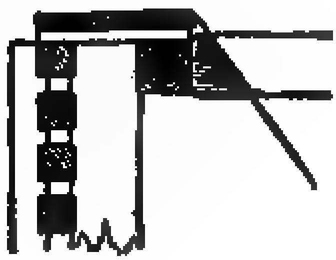


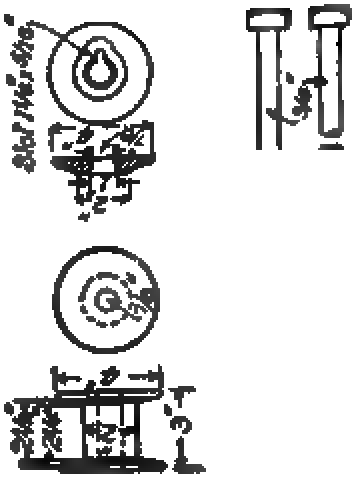
Fig. 84J. Effect of Overdriving Piles.

3rd. Traffic need not be interfered with or endangered while repairs are being made.

4th. The caps may be replaced without cutting or injuring any other part of the structure in the least.

5th. Economy in material, because it is not necessary to replace the whole cap unless both sticks are decayed or injured, but only that part which is no longer in serviceable condition.





Standard Pile-Trestle, Denver & Rio Grande Railroad.

Speaking of the effect of over-driving piles, he says: It is dangerous to attempt to drive piles to a very small settlement under the last blow of the hammer. * * * A case occurred on the Boston, Hoosac Tunnel & Western Railway, clearly illustrating the bad effects from over-driving. In two places this road passed under the Troy & Greenfield Railroad, both of which crossings were at embankments of sand. For the proposed opening, to be spanned by iron bridges on masonry abutments, temporary bents of piles were driven in the embankments to about 22 feet below track-level of the T. & G. R. R. to allow excavation for the abutments, etc., at the under crossing. The fine compact sand caused hard and slow driving. In a subsequent excavation which soon followed it was found that over one-half of these piles were next to worthless, being split or broken from the driving at depth below eight in one or more of the three ways shown in Fig. 84J. Most of the piles failed as shown in 1, some as in 2 and only a few as in 3. The standard pile-trestle, Denver & Rio Grande R. R., shown in the accompanying illustrations, he describes in detail as follows:

Dimensions of Timber.

Floor-System:

Guard-rails, 7 in.×8×32 ft., notched 1 in.

Ties, 8 in.×8 in.×12 ft., notched ½ in. for both guard-rails and stringers, as shown in detail.

Track-stringers, 8 in.×16 in.×32 ft., notched ¾ in. over caps.

Jack-stringers, 8 in.×16 in.×32 ft., notched ¾ in. over caps.

Bent:

Cap, 12 in.×12 in.×14 ft., notched ¾ in. over piles.

Sway-braces, 3 in.×10 in.

Piles, 14 in. diameter at top.

Bank-Bent:

Dump-boards, 3 in.×12 in.×14 ft.; 3 in.×12 in.×16 ft.; 3 in.×12 in.×18 ft.

Battens, 3 in.×10 in.×3 ft.

Dimensions of Iron Details.

Bolts:

¾ in.×33 in.; guard-rail to ties and jack-stringers.

¾ in.×38 in.; ties to caps.

¾ in.×22 in.; stringer-joints; packing-bolts.

¾ in.×18 in.; sway-braces to posts.

Drift-bolts: ¾ in.×22 in.; caps to piles.

Boat-spikes: ½ in.×8 in.; sway-braces to posts.

Cast washers: ⅝ in.×4 in.; under heads and nuts of ¾-in. bolts.

Cast separators: 3 in.×4 in.; between stringer-pieces for ¾-in. bolts.

Trestles.—The life of timber used in trestles and in wooden bridges varies with the local conditions, kind of timber, and location. Just as fast as financial conditions permit, it is considered advisable to replace wooden bridges with structures of a more enduring character. Indeed, upon many railways the heavy traffic and increased weight of locomotives and trains have necessitated changes in the design and construction of bridges from time to time, first from wood to steel, and more recently from steel to stone and concrete. Thus in recent years practically every bridge on the main line di-

visions of the Pennsylvania Railway has been entirely reconstructed of stone or concrete at an enormous total outlay. The same thing is true of nearly every railway of any great mileage whose traffic is sufficiently heavy to justify the expenditure.

Fig. 85.

Where steel bridges have not been displaced by stone or concrete structures they have, almost without exception, been greatly strengthened by reinforcement or else have been replaced by bridges of heavier and stronger construction in order to sustain the increased stress caused by the heavier trains and modern locomotives of such immense tonnage.

But aside from these reasons, it is to the financial interest of railways to replace wooden structures, as far as possible, with others of a more permanent character. Whether these shall be of iron, steel, or masonry, and whether embankments shall have permanent culverts depends, of course, upon local conditions. However, according to the opinion of engineering experts whose experience qualifies them to speak with authority, it is possible to construct such permanent structures more economically after a road is in operation than could have been done when the road was originally built. Experts state that it is to the advantage of railways to spend

$3.00 for permanent work rather than $1.00 for renewals of wooden structures when the average life of the latter is taken into account, and assuming the interest on the investment for permanent improvements to be five per cent per annum.

But, notwithstanding the rapid displacement of wooden bridges by steel and stone there will always remain a vast number of miles of wooden trestling in this country. Some idea of the extent of this mileage may be

Fig 85A. Concrete End Construction Pipe Culverts

had when it is remembered that according to a report on American Railroad Bridges prepared by Theo. Cooper and presented in 1889 to the American Society of Civil Engineers, there were in that year 2,400 miles of single track railway-trestle composed of 150,000 separate structures, having about 730,000 spans. After making due allowance for the reduction made in this total by the

substitution of more permanent structures in some instances, it is questionable whether the total would not exceed the original by reason of the enormous additions to railway mileage through new construction in the past fifteen years.

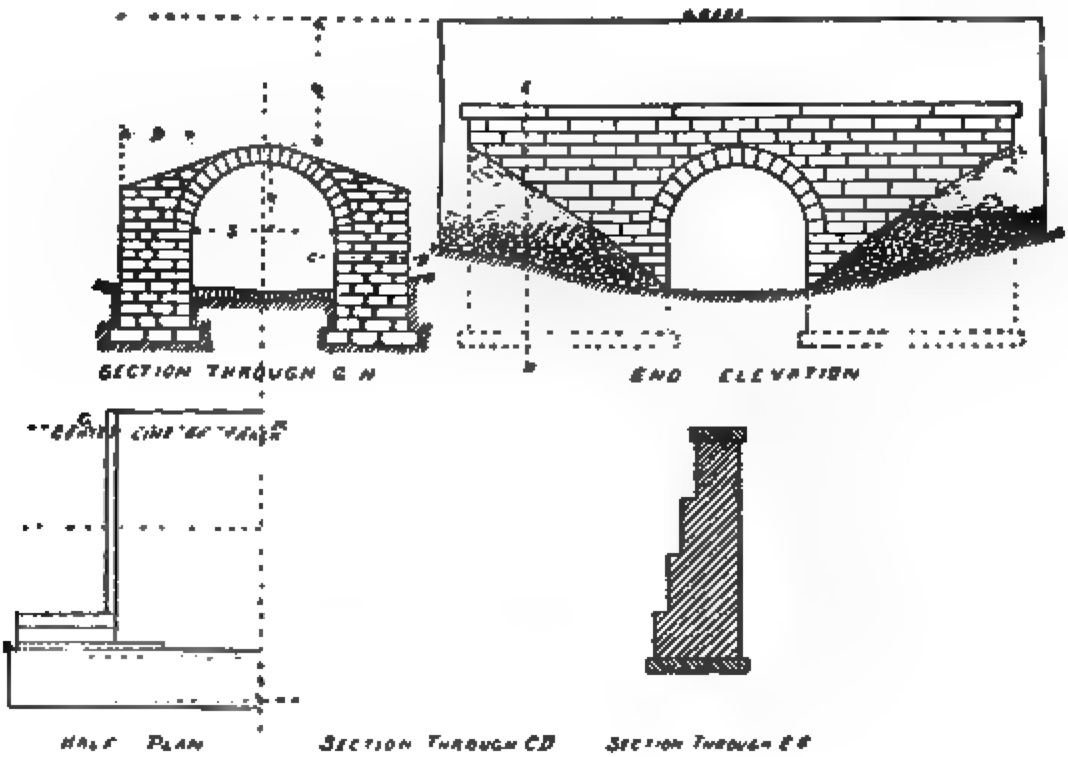


Fig. 85B. Stone Arched Culvert.

Timber having such an important place in railway structures tends to increase the responsibilities of the bridge and building department, whose chief must exercise eternal vigilance in efforts to have bridges and trestles properly inspected, repaired and renewed and measures taken for protection against flood and fire.

The bridge and building department is therefore one of much importance. It is usually controlled by the Chief Engineer. Sometimes it is headed by a general officer with the title of Bridge Engineer, who has under

him several superintendents or supervisors each in charge of an extensive division, and to these the foremen in charge of bridge carpenter gangs report.

The number of miles over which a superintendent of bridges and building has jurisdiction depends, to a large extent, upon the character of the road, whether single or double track, few or many bridges and trestles, and whether the culverts be of iron or stone, and the bridges constructed of wood, iron, steel, stone or concrete. Generally speaking a single track road division is from three to four hundred miles.

Two regular inspections of all bridges and buildings is generally made each year. One in the spring after frost is out of the ground, the other in the fall before freezing weather sets in. Each bridge and building is numbered, the numbers running in consecutive order, and the inspection begins, as a rule, with the lowest or first number and proceeds in numerical order. The inspection in the spring is to ascertain the damage done by frost, ice, etc., during the winter and to determine how much work must be done during the approaching summer. The fall inspection reveals whether the summer's work has been properly done; whether the structures are safe and also what repairs and renewals are necessary the following year. The notes taken and the reports made enable an approximate estimate of the labor and material needed the next year to be made up during the early winter.

The Inspection.—The following instructions govern, in a general way, what should be noted in making inspections. The rules are condensed and compiled from different authorities upon the subject:

Wooden truss bridges must be carefully examined. The truss rods must be taut but not strained, the adjustment being made when there is no load upon the structure. The camber must be true and uniform for top and bottom chords. Under a live load the deflection must not be excessive. It should be the same for both trusses. The test for this should be made with an instrument. Careful search must be made for cracks in attachments of cast iron, as post shoes, angle blocks,

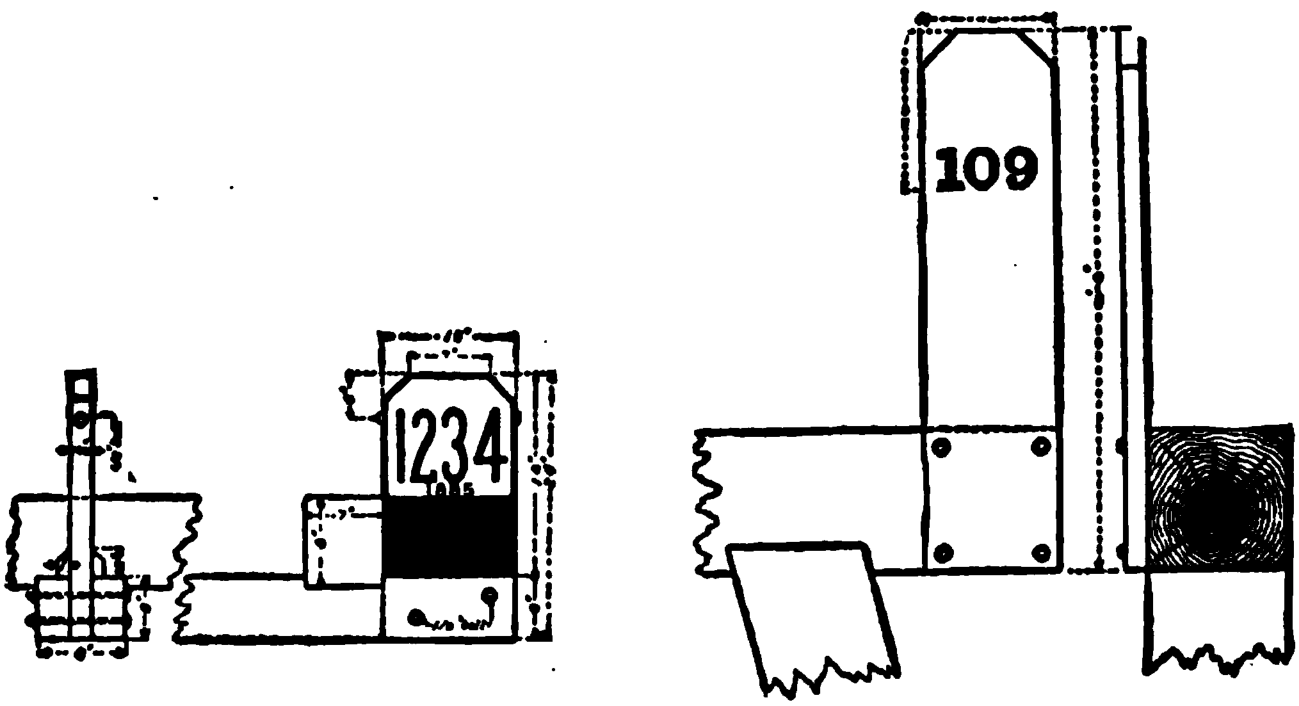


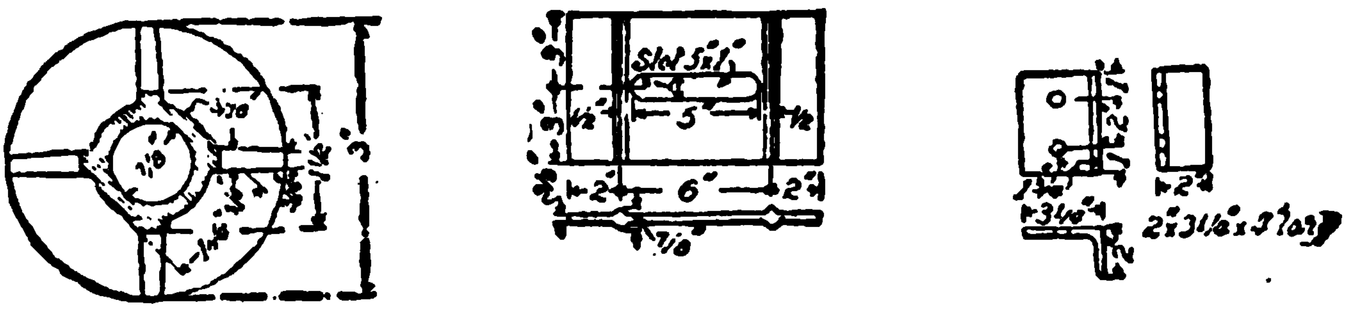
Fig. 86. Bridge Numbers.

chord boxes; they should also be examined for indications of displacement and for openings in bottom chords or crushing of timber in top of chord. Shearing of clamp daps should be made a note of. Nuts on bolts must be tight. Where barrels of water or other means are provided for fire protection they should be seen to be in proper order and notes made thereof.

Great care must be taken to examine timber structures for decayed and broken members. Any such found should be carefully noted and their exact location given

to guide foremen when making repairs. Frame bents or bracing, longitudinal and sway, must be securely fastened to the sills, caps, plumb and batter posts.

Bridge piers, abutments, arched culverts, stone box culverts and retaining walls must be examined for any indications of settlement in foundation. For cracks either in the face, seams, or stone and for walls out of line because of too much pressure of embankments. Careful inspection of foundations to detect the scour of the stream must be made, the rip-rap examined to see the quantity is sufficient and that it is so placed that it will not be washed away by the current during a freshet. To ascer-



Cast-iron Spool. Corbel-stringer Separator. Angle-lug.

Fig. 87.

tain that embankments will not be undermined by water running through the outside of culverts when constructed of iron pipe they must be carefully examined. The outlets of all culverts—iron pipe, stone arch, and box—should be examined to see that the paving is not being washed down. The inlets to them must also be inspected for brush and drift brought down by freshets, choking up the openings and causing water to flow over embankments.

Inspectors should ascertain when inspecting iron bridges that bed plates and rollers are clean. The rollers

Fig 87A Standard Framed Trestles, Pennsylvania Railroad.

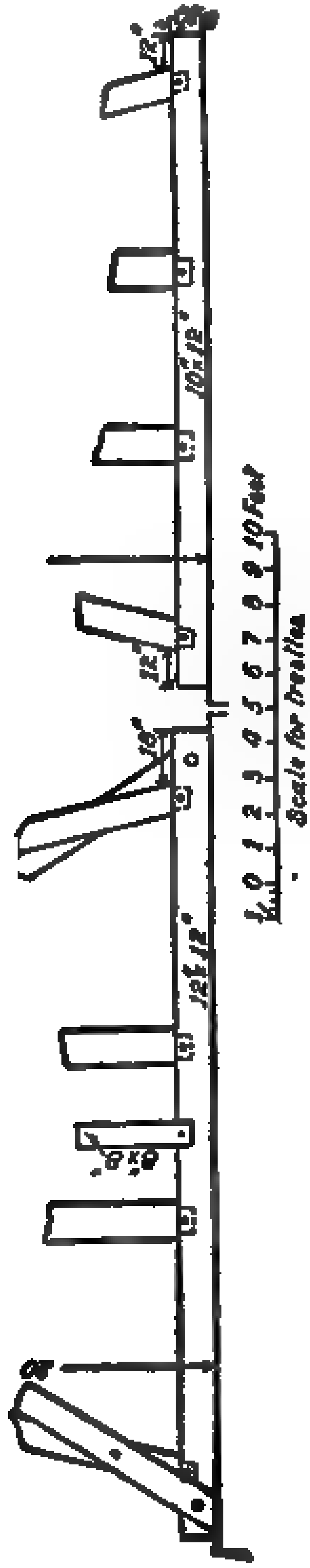


Fig. 87A. Standard Framed Trestles, Pennsylvania Railroad.

ought to stand so they move squarely back and forth with the truss. Examinations for splits in connecting angles in the connections between floor beams and trusses must be carefully made. Suspended floor beams should receive particular attention to see whether they are tight against the post bed or free to move. Tension can be tested by springing tension members, care being exercised to detect distortion or crookedness in the members. Counter lateral and vibration rods must be taut, not strained, and adjustment made when no load is upon the

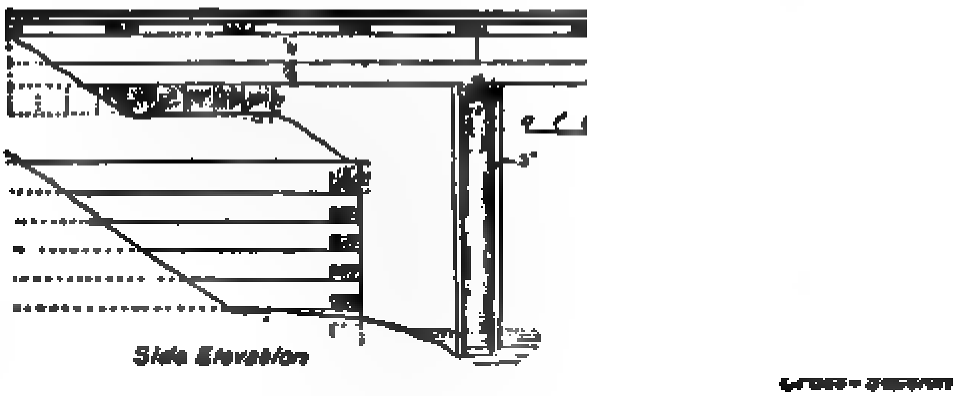


Fig. 87B. Pile Trestle with Earth Roadbed, Louisville & Nashville Railroad.

bridge. The center line of all tension members ought to be in the line of the strain, and there should be no twists in lateral struts and top chords; these should be perfectly straight. Lightly sound field driven rivets to see if tight. Movement caused by rust streaks or indicated by other signs in members must be noted. The camber of both top and bottom chords must be regular and similar; the deflection under a live load should be the same for the two trusses in the same span and must not be excessive.

Overhead bridges for highways must be inspected in the same manner as truss bridges, and coal sheds and water tanks examined for defects in foundations and for decayed timber.

Fig. 88. Hartley and Teeter Gasoline Motor Car

In examining buildings and platforms the condition of the floors, siding and plastering must be noted and care taken to carefully inspect for defects in chimneys, the condition of roofs, fastenings for doors and windows and decay in sills and defects in foundations should be looked for carefully.

The foregoing is merely a concise, general summary of the more essential particulars of making a semi-annual inspection. More specific details can perhaps best be

given by quoting in full the rules and regulations and instructions regarding bridge and building inspections as in force upon two great railway systems which traverse almost every character of topography ever encountered in railway engineering. These instructions governing in the first instance the Northern Pacific Railway, and secondly the Southern Pacific, should be found most valuable and easily conformable to the local conditions of railways anywhere. The Northern Pacific rules are as follows:

The division engineers will make occasional examinations of the condition of all important bridges and culverts. In an emergency they will, on their own authority, report such repairs as they may deem necessary for safety, to the division superintendent for immediate attention. In other cases they will make their reports to the chief engineer, who will decide on the amount and character of the work to be done.

Great care must be taken by division engineers and supervisors of bridges and buildings, to whom the security of structures is intrusted, and to make such inspections so thorough and the records thereof so complete as to convey definite and precise knowledge of the conditions of each and every structure at the time of last inspection.

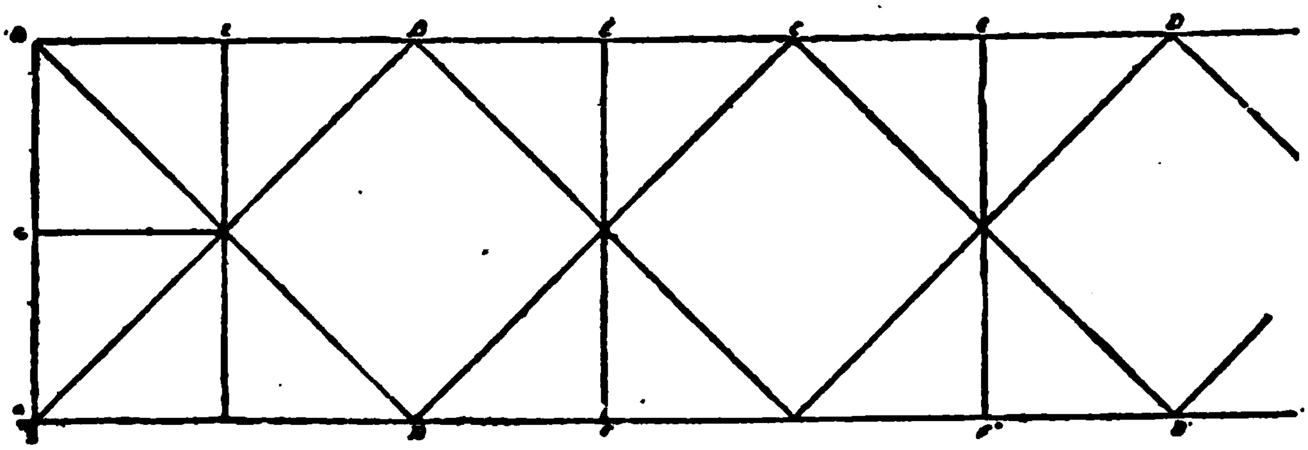
There will be two regular inspections each year, as follows:

1. January, by the supervisor of bridges for each division of all truss and large trestle bridges.

2. In September, by the division engineers and supervisors of bridges, of all bridges, culverts, waterways, etc.

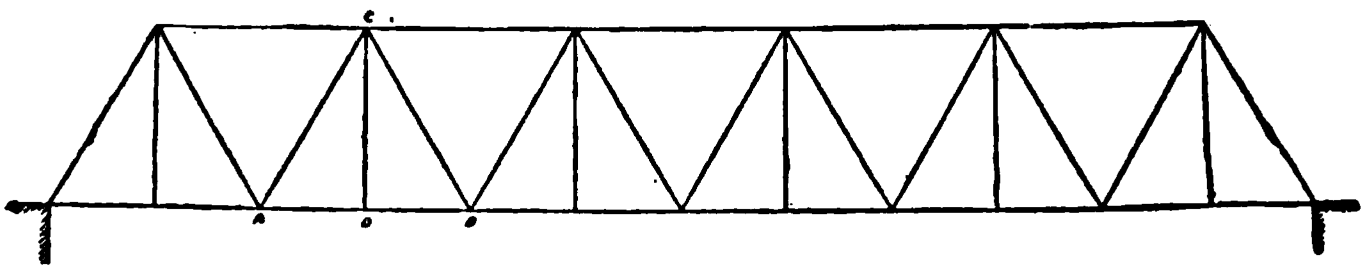
In addition the supervisors of bridges must at all times make such inspection as may be necessary to insure safety.

The September inspection must be made with special reference to obtaining information for estimating the cost of renewals and repairs, and for the material required for the ensuing year.



MODIFICATION OF THE WARREN TRUSS FOR LONG SPANS.

This is type of the truss used for the bridge across the Mississippi River at Memphis, Tenn. The lower chord is 75 feet above high water. The span is 621 feet.



MODIFIED FORM OF WARREN TRUSS.

As the length of the Warren truss is increased and the height of the truss also increased, making the points A and B of the triangle A B C too far apart to support the floor system, a vertical C D is added to support the floor at the point D.

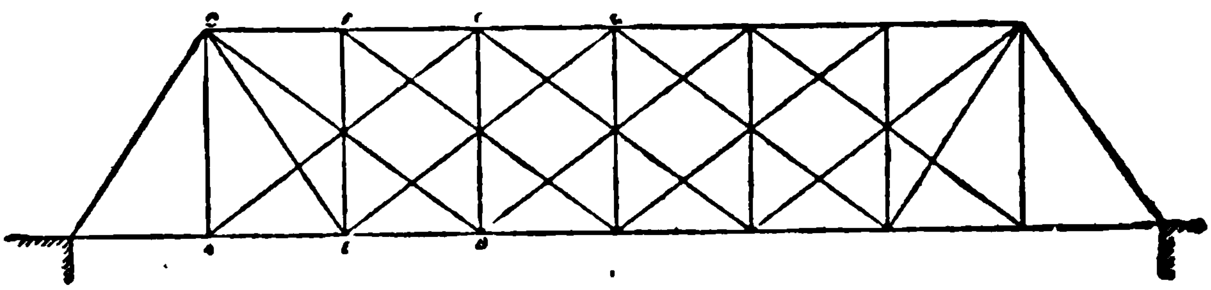
Fig. 89.

The supervisors of bridges will forward the report of these inspections, with an impression copy of the same, to the division superintendent for approval. Division superintendents will forward both copies to the division engineer.

The supervisor of bridges will make such further inspections as he finds necessary to keep thoroughly posted as to the conditions and safety of all bridges and culverts on his division.

Division superintendents will arrange to obtain the record of extreme high water at the time of each flood, or extraordinary freshet, at all bridges, culverts and openings.

Section foremen should be instructed to go over their sections at such times and take the measurements from top of tie to the extreme high water mark and report such measurements, giving the number of the bridge or opening, to the division superintendent.



WHIPPLE TRUSS OR DOUBLE INTERSECTION PRATT.

As the length of the span is increased, the height of the truss must be increased, and to place the oblique members at or near an angle of 45° in a Pratt truss or 60° in a Warren truss, the length of the panel must be increased. Modifications must now be made of the simple trusses to afford intermediate points to support the floor system. The Whipple truss is a modification of the Pratt truss made for this purpose; A B C D represents a panel of a Pratt truss; an extra vertical E F and extra obliques D E and E G are added to afford support to the point E to support the floor system.

Fig. 90.

Division superintendents will forward this information to the division engineers, who will retain copy and forward the information to the office of the chief engineer for record.

Supervisors of bridges will furnish the division superintendent monthly reports of all repairs and renewals of

bridges and culverts, executed during the month. These reports will be forwarded to the division engineer, who will check same against the inspection requirements, for the purpose of insuring compliance with such requirements.

At the completion of the work the supervisors of bridges will forward a report to the division superintendent, showing all changes in the class of structure,

Fig. 91. Bridge Hand Car.

details of construction and length, height and position of structures; also the cost of labor and material expended. This report will be forwarded to the division engineer, who, after recording same, will send it to the chief engineer for final record.

Following the September inspection, estimates of the cost of repairs, renewals and replacements recommended

for the ensuing year will be prepared by the division supervisors and division engineers, which will be tabulated and forwarded through the office of the chief engineer. The character and extent of renewals and improvements will be determined from this report. Descriptions and estimates will be given for permanent structures, wherever same appear desirable or economical.

This report will show the cost of necessary repairs recommended for the ensuing year; the average annual cost of such repairs; the total cost of the structure upon which repairs are recommended, and also the total cost and annual interest upon permanent structures, where such structures are recommended.

All changes, additions and expensive renewals of bridges, culverts or other important structures shall be made only upon the properly approved plans and estimates of the chief engineer, who will make contracts for and superintend the work.

Instructions to Inspectors.—Note-books of inspection must be filled out at the structure after a careful examination has been made of each of the points itemized in the blanks, using in cases where there are a number of spans in which defects are observed, a properly noted column for each span. When the spans are all in good condition one column only need be used, but the number of spans should be noted.

Designate the separate spans of the bridge by numbering them in the direction of the bridge numbers on the division, and the separate bents or piers in the same manner, commencing with abutment bank-bent or sill as No. 1. Designate the truss as the right or left, locating points on it by numbering the panels in the same direction as the stands are numbered.

When wooden structures are four years old, such members as by their position are particularly liable to decay must be tested by boring, the holes to be plugged up as soon as the inspection is completed.

When making regular inspections the inspectors will take a statement of the results of the last examination relative to such structures as required attention at that time, and in reporting on these structures special notice must be made as to whether the repairs and recommendations of the previous examinations have been fully carried out or not, and whether the work is in accordance with the standard plans.

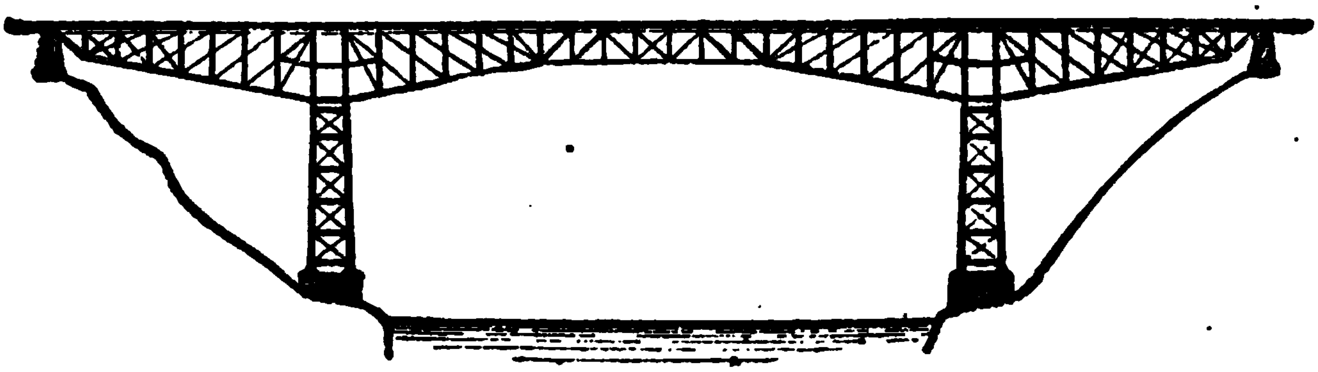


Fig. 92. Cantilever Bridge.

Instructions Regarding Inspection Reports:—(Numbers and directions in these instructions correspond with numbers and abbreviations on report blanks.)

1—Does water-way require straightening, cleaning out or enlarging above or below structure? Does structure afford ample water way? Is rip rap needed to maintain channel or protect roadway?

2—Note line and surface, also condition of rails, joints and fastenings on bridge and approaches. See that rails are braced on curves where necessary, and that track on approaches is firmly bedded, avoiding shock or jolt to train as it passes on to bridge.

3—Note any rotten, split or otherwise defective bridge ties, giving number, size and kind.

4—See if guard rails are in line and bolted or spiked down tight.

5—Note condition of caps and stringers, particularly at points where they bear against other members.

6—Note if plumb and batter posts are crooked, split or decayed, and if bents stand plumb.

7—See if trestle towers or bents are properly sway-braced, and all braces longitudinal and transverse are drawn up tight and have sufficient bolts or spikes to hold them properly.

8—Note particularly the condition of piles where they enter the ground or water. See that they stand properly.

9—Examine each pier and abutment as to joints, settlement, imperfect stones, cracks or other defects; note if work needs pointing up, or if cracks have opened since last pointed. Make such measurements as will locate position or cracks, and note on sketch on back of the report blank. Condition of rip rap, if any. Is rip rap needed to prevent undermining? How much? Condition of pedestal stones, and whether bridge seat is clean and water drained off.

10—Note condition of culvert and retaining walls. See if they are yielding by settlement or bulging from the pressure of the embankment.

11—Condition of rain, or covering stone, of box or arch culverts.

12—Note condition of paving and rip rap, and that same is so placed that it cannot be undermined by washing.

13—Does pipe drain need head or tail wall to protect

embankment from washing? And does it clear itself of water?

14—Does timber box need to be replaced with masonry, or culvert pipe? If so, give dimensions required to give ample water way, and give height from bottom of stream to rail.

15—See if bed plates and rollers are clean, and if the latter stand so as to move squarely back and forth with the truss. See if pedestal takes an even bearing on rollers. Examine anchor bolts.

16—Observe particularly the condition of wall plates where bolster rests upon them. Note any appearance of crushing or decay.

17—Note condition of bolsters and corbels. See if holes are bored through them where they cover the spaces between chord sticks, to prevent the collection of water, and if there is any indication of decay where they are in contact with chords.

18—Angle blocks and all cast iron members such as chord boxes, post shoes, etc., must be examined for cracks and for any indication or displacement by reason of daps splitting or timber crushing. A hole of one-fourth inch in diameter, if drilled at the end of the crack, will frequently stop its extending farther.

19—Note particularly any appearance of opening of bottom chord joints. Wooden bridges over four years old should have gauge blocks at all joints in the middle half of the span, made by fastening two planed and squared blocks 1 by 2 inches, 6 inches long, to the chord sticks with screws, and scribing a fine line across both. Any movement of joints should be noted, giving location and amount, scribing a new line from the old one on the out-

side block across the inside block. See if clamp daps are shearing.

20—See that all chord and packing bolts are tight. Nuts on all bolts through guard rails, ties stringers and floor beams must be secured in place by burring the thread of the bolt at two or three places, with the center punch or cape chisel.

21—Note any signs of decay or crushing in packing blocks, and see that clamps and keys are in proper condition.

22—See if gib plates are distorted or crushing into the chords; if they are, give their location and dimensions, number, size and spacing of rods passing through them. Give size of rods over threads.

23—Note condition of sides and roof of covered bridges, or of chord and end post covering.

24—Notice particularly the connections between stringers and floor beams; see that connecting angles are not split, either in the angle or through in the line of the rivet holes. For wooden stringers, note condition as to soundness and bearings.

25—Notice particularly the connections between floor beams and trusses for evidence of imperfect bearing; or splitting of connecting angles. If suspended, notice if they are up tight against the post feet or free to move.

26—Test equality of tension in tie bars by springing them. Look for any signs of distortion or crookedness in bars of end panels of bottom chords. Howe truss rods, counter lateral and vibration rod must never be allowed to hang loose. They must not be adjusted while a load is on the bridge. They should be tightened enough to give close and even bearings, but must not be overstrained, as unnecessary strains are put on compression

members if too much power is used in adjusting tension members. See that center line of all tension members is the same as the line of the strain.

27—Examine carefully especially at the joints.

28—See if posts, lateral strutts and top chords are straight and free from twists. On wooden bridges, see if braces are up in place, taking a square bearing at ends, and note if any warping is evident. Note their condition as to soundness.

29—Examine all lateral connections and see that lateral tension members are straight. Examine bracing in iron trestles.

30—Make particular examination of all hangers, testing each nut to see that it is tight. A streak of white paint drawn across a nut and bearing will indicate any movement. These nuts should be screwed up tight and secured by burring the thread of bolt and nut at two or three points with the center punch or cape chisel.

31—Note any pins which indicate the movement of any of the members coupling on them, or that have loose nuts. All pins and nuts should have a streak of white paint across the nut and pin end.

32—All field driven rivets in floor beams and stringer connections should be lightly sounded to see that they are tight. Also lateral connection rivets in riveted trusses, and any intersection or other rivets which indicate by rust streaks, or otherwise, that there is movement at that point.

33—Note if there are any members, such as closed columns, pedestals, etc., which catch and retain water by reason of not having proper drain holes.

34—Note carefully the line of each truss by the top chord and by points on the floor beams equidistant from

the center of the posts. Also note the camber by the top and bottom chords, whether it is true and uniform or irregular.

35—Look for loose rods, hangers, loose braces, unequalized timbers and other defects which require adjusting in order that each of the different parts may have proper bearings and carry its proper part of the load.

36—Note any undue vibration of the structure under live load.

37—Note excessive deflection of the structure under live load seeing if the two trusses have the same deflection.

38—See if any rust spots are apparent under the paint. Note if structure needs repainting. Iron bridge work should be scraped and repainted as often as necessary to preserve from rusting.

39—Note such wooden structures as require barrels to add to their safety, giving number required. State condition of such barrels as may be in position. On all bridges of such magnitude as to require a watchman, there should be a foot-plank between the rails securely fastened to the ties to facilitate crossing the bridge quickly in emergencies, such as fire, or danger to trains. Note if ladders, either fixed or portable, are required for the safety of the structure or to facilitate inspection.

40—See if material, drift-wood, weeds, grass or other rubbish is properly removed and burned, or otherwise disposed of.

List of abbreviations for class of structures.

W. B.—Wooden or timber box culvert.

S. B.—Stone box culvert.

S. A.—Stone arch culvert.

T. P.—Title culvert pipe.

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C. P.—Cast culvert pipe.
B. D.—Blind drain.
W. C.—Wall culvert.
P. B.—Pile bridge.
P. C.—Pile Culvert.
T. B.—Trestle bridge.
H. T.—Howe truss.
C. T.—Combination truss.
I. T.—Iron truss.
D. S.—Draw span.
P. G.—Plate girder.

ERECTION OF STEEL BRIDGES.

General.—Engineers, inspectors and contractors are expected to make themselves thoroughly familiar with the general and special specifications governing the work.

All material received must be carefully checked, recorded and reported immediately upon receipt of same, in accordance with the rules. Shortages should be reported immediately. Material received should be checked against complete bill of material, and every effort made to avoid delay to the progress of the work, by failure to receive material, including false work, tools, etc., etc.

The engineer in charge must cause to be kept an accurate record of the cost of the work, including material and labor, keeping separately each class of work, such as rigging up, unloading, repairing, raising, fitting, riveting, cleaning, painting, framing, bolting, contractor's pay-roll, character of plant, framing and erecting false work, and removal of same. A diary must be kept containing the dates of commencing and completing different classes of work, and all other general information of

value. A record, or copies of all orders or instructions, issued or received during the progress of the work and the daily force account should also be kept.

The engineer in charge must check all distances and elevations on plans, before laying out the work, and will be held responsible for any errors that may arise through neglect on the part of himself or assistants, properly to verify and recheck, plans, points and elevations, given for the erection of the structure. Distances between centers and elevations of finished tops of masonry are especially important, and should be rechecked as often as may be necessary in order absolutely to insure against errors. The sum of the heights of the component parts forming the structure should be carefully checked against the total finished height, above assumed datum, to base of rail. The sum of all detail lengths must also be checked, with equal care, against the total length from the fixed initial point.

Insure that the material shall not be injured, nor dangerously strained during the operation of loading, unloading or handling same. All defects in workmanship or material must be remedied as soon as detected. A thorough inspection must be made for defects in painting, cleaning, reaming, spots of shrivelled oil or paint, chips, burrs, sharp edges and black or rusty spots on steel, scale, cinders and scratches, particularly in joints and around rivet-heads, brush-hairs, or other foreign matter covered over with paint or oil; all such defects shall be remedied immediately, and noted in detail, to provide full information, in case of claims for extra compensation.

Slight bends in members shall not be straightened unless strictly necessary on account of the danger of over-

straining connections and rivets. Connection plates, if slightly bent or twisted, shall be straightened cold; if bent so sharply as to require heating, the whole piece thus heated shall be subsequently annealed. All shop rivets, or any piece of member thus straightened, shall be properly tested.

Particular care will be taken to insure free expansion and contraction, wherever provided for in plans. Any departure in dimensions amount of camber or otherwise, of material received, from plans and specifications, must be noted and reported immediately.

All machine-fitted bolts shall be perfectly tight, and should be burred or otherwise checked to prevent nuts from becoming loose, and no unfilled rivet or bolt holes should be left in any part of the structure.

Fitting and Chipping.—The material must be assembled in accordance with the match marks, and no interchange of pieces must be made, unless absolutely necessary in order to avoid chipping and fitting or serious delay.

Fitting and riveting of connections (especially angles) in cases where pieces are short or full, must be done in such a manner that the metal is not unduly strained or cracks caused.

Dishonest or incompetent workmen frequently fill cracks with paint, putty, cinders, dirt, oil or filings, for the purpose of deception. A close inspection must be made for this.

Wooden rams or malls must be used in forcing members to position, in order to protect metal from injury or shocks.

Chipping of rivets, angle flanges and edges of plates must be done without breaking out metal. Chipped edges

must be finished off with a file, and all concave corners must be rounded off. Chipping with a sledge will only be permitted in exceptional cases, and must be done without leaving fractured edges.

Riveting.—In driving rivets the dolly and die should be placed directly opposite each other, at right angles to the riveted surface, to insure straight driving. Rivets must be driven while at an orange heat, and no burnt rivets should be used.

After riveting each rivet must be tamped with a hammer to insure they are tight, and the heads must be well formed, concentric with center of rivet, and closely fitted against the riveted surface.

Defective rivets can usually be detected by their color, or by sound when tapped with a hammer, and all loose or burnt rivets must be immediately cut out and replaced.

In cutting out rivets be careful to ascertain that other rivets in proximity have not been loosened.

Tightening up, recupping and caulking old rivets will not be tolerated, except that occasionally recupping of sharp rivets do not form part of the important connections or do not directly transmit stresses.

Countersunk rivets must be inspected after chipping heads, and no unnecessary chipping should be permitted.

Painting.—The specifications under the head of cleaning, oiling and painting must be strictly carried out.

An accurate account should be kept of the quantities and proportions used, of pigments, oils, and other ingredients, and the quantities by weight or fluid measure, of the resulting mixtures, ascertained. A record should be kept of the quantity applied of each coat, and its proportion ascertained to area or weight of material covered.

Paint should be thoroughly worked in all corners and

joints, and narrow openings, covering edges and sealing up all lines of contact between parts.

Unless otherwise specified, the ingredients and proportions of the mixture, for the three coats, shall be as follows:

First coat—30 lbs. pure lead to one gallon pure boiled linseed oil, 1-3 pint pure turpentine.

Second coat—25 lbs. pure lead to one gallon pure boiled linseed oil, ¼ pint pure turpentine, lamp black, quantity not to exceed twelve ounces.

Third coat—15 lbs. dry pigment, Cleveland Ironclad, purple band No. 3, to 1 gallon of pure boiled linseed oil.

The following are the rules adopted by the Southern Pacific Company, in relation to Bridges and Buildings:

The records kept by the Superintendent of Bridges and Buildings should give the date when the piling was driven and the length from the point to the cut off, so that he can judge as to the security of the foundation. The date when all sills, plumb and batter posts, caps, corbels, stringers, ties and guard rails were placed in bridges should be kept in a convenient manner for ready reference, and this record book should be taken along when the inspections are being made.

The first aim of the Superintendent of Bridges and Buildings should be to secure a good foundation for all his repair work; to keep the structure thoroughly braced both while making the repairs and afterward.

All joints should be made to fit snug and the bearing should not come on one corner or edge of a stick of timber, but should come evenly over the whole section of the stick as a plumb post in a trestle or a diagonal or a member of the top or bottom chords of a Howe truss. The caps of a pile bent or the sills and caps of a frame bent

should be square with the track on a tangent and radial to the track curve. No repair work should be allowed which throws the strain on a member outside of its center line, thus tending to bend or buckle the member.

In truss bridges the floor beams should always be placed at right angles to the track. This not only makes better riding track, but distributes the load uniformly between each truss. The main and counter braces should always be in their proper condition on the angle blocks before adjusting the truss rods.

When the span has the required camber and the counter braces are tight, those individual rods in each panel which may be slack should be tightened until each rod in the panel is strained in proportion to its area. When the rods are slack, counter braces loose, and camber less than required, commencing at first set of rods at either end of truss, tighten them evenly, not enough to buckle the counter braces but enough to so firmly fix the ends of these against the angle block that an ordinary blow with a maul will not start them from proper position, following which, treat the first panel at the opposite end of truss in the same manner. This done, adjust the second panels from each end, and so on, working alternately from each end of the truss toward the center until each set of rods has been put in adjustment. Regardless of how much care has been taken to get the tension on all rods even, many rods will be found to require a second adjustment in order to leave the truss in perfect condition.

Be very careful not to overstrain small rods by exerting too much force on them.

The force required to tighten a large rod is sufficient to break a small one and good judgment should be exer-

cised to the end that each rod be strained only in proportion to its size.

Do not attempt to increase the camber in a span by tightening the rods if the counter braces are all tight against the angle blocks. While it is possible to increase the camber in this manner, the result is accomplished at the expense of high initial strain on the rods, buckled corner braces, broken angle blocks, and sheared packing keys and clamps in the chord, each and all of which are much more dangerous than want of camber.

In practice it frequently occurs that the camber can be somewhat improved, in adjusting a truss, by slacking off the rods slightly in three or four panels each side of the center of the truss, before commencing at the ends of the truss to finally adjust the rods.

In order to permit the angle blocks to be readily placed in position, the seats for same in the chords are frequently framed with play enough to allow them to move slightly from their original position when subjected to the thrust from the main braces, the bottom angle block moving toward the end of the truss, and the top angle block toward the center of the truss. As this increases the length of the panel in the direction of the main brace and shortens it in the direction of the counter brace, it is obvious that, in order to preserve the original camber of the truss, new braces should be provided throughout, but usually the movement of the angle block is so slight that, while seriously affecting the camber, the angle of the brace is not changed enough to be noticeable as regards its bearing against the angle block.

In such cases the counter braces can be shortened sufficiently to bring the truss to required camber without injurious effect on the truss.

In no instance should this be done without first receiving the sanction of the Bridge Superintendent.

In adjusting the end panel rods of long heavy trusses, it is advisable to take up a portion of the dead load by means of a screw jack placed under the panel to be adjusted, which relieves the strain on the rods and assists in raising the truss to its proper position.

The object in doing this is readily apparent from the fact that the wrench can be applied to only one rod at a time, and unless some assistance is given it, half the weight of the truss between it and the opposite abutment is thrown upon the rod.

A block should be placed between the jack and the chord of sufficient length and strength to distribute the thrust from the jack over all the strands of chords to avoid any movement of the strands upon one another.

Always remove the jack before allowing trains to pass over the bridge.

When jack screws cannot be used, nuts should be turned a very little at a time on each rod in rotation. Nuts on truss rods must be screwed up by applying a steady pressure to the wrench, no advantage being taken of the slack between the socket and nut to produce a blow on the nut by an oscillating movement of the wrench, as it not only destroys the shape of the nut but has a tendency to injure both nut and rod.

Always support the truss by a post or bent placed under the next panel before removing the end panel main braces and the old abutment block, and do not remove it or allow trains to pass over the bridge until the new block and braces are in place and the truss is again in adjustment.

Where a broken angle block in bottom chord is to be

replaced with a new one, a post or bent must be placed under the next panel point toward the center of the truss, sufficiently strong to support the portion of the truss which would otherwise be unsupported if the braces were removed. When it is impracticable to support the truss in the above mentioned manner, two rods should be provided of sufficient length to run diagonally and in line with the counter brace from the top of the truss over the panel point in which the angle block is to be replaced, to the bottom of the truss under the next panel point toward the center of the truss with heavy wooden gibs top and bottom.

The gibs must extend several inches beyond the chord on each side and have holes bored through them at the proper angle, so that when the rods are in place there will be one on each side of the truss. The rods are to be tightened until the load on the truss rods is removed, when the main and counter braces, truss rods and angle block can be removed and replaced.

In replacing an angle block in the top chord support the panel point in which the angle block is to be changed in the same manner, taking care to leave in all braces which do not abut on the angle block to be replaced.

No train should be allowed to cross the bridge until the truss is in adjustment and the support, if from the ground, is removed.

Angle blocks are frequently broken by the shrinkage in the timber of the chord allowing the gib to bear against the ends of the angle block tubes. In this case hard wood shims of sufficient thickness must be placed between the gibs and chord to keep the gibs away from the tubes. In doing this do not slack the truss rods until temporary rods passing through strong wooden gibs have

been put in place, one on each side of the chord, as near to the panel point as possible to keep the truss in shape while the rods are loose.

If more convenient a post can be placed under the panel point, which is to be removed before allowing trains to cross, and truss must be in adjustment for either method before allowing trains to cross.

The recurring adjustment of the truss and lateral rods in a deck truss, and the inevitable reduction in the distance between the chords resulting from it, makes it necessary to shorten the transverse braces from time to time so that they may not be excessively strained. They must be kept tight, but not tight enough to buckle the timber or displace the strands, against which they abut from their proper position in the chord, as this would result in broken keys and clamps.

BUILDINGS.

In regard to buildings the architecture of modern railway terminal stations has become a field for the specialist. Indeed noted engineers are making it their lifework. The extreme types of passenger terminals in America are found in the Grand Central Station in New York City, the Union Station in St. Louis, the Chicago, Milwaukee and St. Paul Station in Omaha and the new Pennsylvania terminals now constructing in New York, the Union Terminal in Washington, D. C., and the proposed new terminals in Chicago. There are, of course, many others possessing novel and interesting features, each worthy of careful study, but for the purposes of this treatise they will not be considered. Indeed it is beyond the scope of the limited space which can be al-

lotted to the subject in this volume to give an adequate description of only the largest passenger terminals, therefore only the more salient features of a few can be given.

Regarding the Architecture of Terminal Passenger Depots Mr. Walter G. Berg, C. E., in his excellent work on "Buildings and Structures of American Railroads," says:

A terminal depot involves such heavy expenditures, that it is a mistake to build it at the start on too small outlines. The size and ground-plan layout should correspond not only to the actual requirements of the business to be expected in the near future, but should be planned for the largest possible growth of the business that can be plausibly expected for a long term of years, as subsequent alterations or enlargements of a previously adopted plan on a smaller scale are very difficult and expensive to make. The importance of planning for the future should be especially emphasized in acquiring terminal lands, as additional ground can be obtained prior to the construction of a terminal depot at much less rates than if the railroad company waits till the value of the neighboring property is not only enhanced, but the necessity for acquiring the adjoining tracts becomes a vital railroad question of public importance. It is far preferable to build at first only part of a large layout, extending the buildings and adding extra facilities and more permanent arrangements as the business increases and the railroad company's exchequer allows it. Thus an extensive train-shed can be replaced temporarily by platform shed roofs, or the length of the shed reduced and covered platforms run out along the tracks beyond the shed, or the width of the shed reduced to one span, if the final plan contemplates several spans. The accommoda-

tions for baggage, express, mail, emigrants, etc., which are usually provided for in wings, detached buildings, or end pavilions, can be furnished of a more temporary nature or provided elsewhere temporarily. The import of these remarks is to emphasize the necessity in building a large railroad terminal of acquiring sufficient land at the start and making the general plans to cover the probable requirements for a great many years, even if all the ground is not occupied at once or the entire building erected immediately as planned.

The class of building materials to use and the general finish of the buildings will depend on the amount of money available for the structure and the class of materials in general use or easily obtainable in each particular section of the country. It can be said, however, that, owing to the importance and cost of the structure, together with the serious difficulties and delays that would result to the entire passenger business of the road in case of a fire, it is desirable to have as fire-proof a structure as possible, equipped with the best fire-service provisions.

Relative to the style of architecture to be adopted for a terminal passenger depot, it will depend, more or less, on the importance of the station, the surroundings, the proximity and style of neighboring buildings, the size of the structure, the desires of the railroad management, the wishes of the public, the prevailing class of architecture and building materials in general use in the locality in question, and the individual views of the architect making the design.

In general, however, it can be said that the character of the building should be expressed to a certain extent in its exterior, the structure should be built on broader and

grander lines than local depots, presenting a bold and prominent front, relieved, however, by suitable disposition and divisions of the wall surface, the fenestration, roof lines, and other details, without detracting from the general features of the design as a whole.

Train-sheds are used in connection with a terminal passenger depot, to cover the tracks and platforms in front of the depot on which passengers take or leave trains. At very large terminals, situated in cities, train-sheds are a necessary requirement of the depot structure; but at minor terminals, especially where the appropriation for the buildings is limited, satisfactory results can be practically obtained by a series of platform-sheds. If the general lay-out at the start is made with a view to building eventually a train-shed, when the business warrants it or funds are at hand to do so, then the introduction of temporary platform-sheds is a very commendable solution of the question. The first cost of the train-shed can also be diminished by reducing its length or omitting additional spans, where the final plan contemplates several spans, and substituting, if required, light temporary platform-sheds. At the Union Depot at Kansas City, Mo., one-legged iron platform-sheds are used on the longitudinal platforms between the tracks, while large arched arcades, 50 feet in width, cover crosswalks connecting the longitudinal platforms with the covered platform along the face of the depot. Excepting during very stormy weather, this system provides ample protection for passengers and baggage, and offers, in addition to cheapness of first cost, the great advantages of being light, airy, and not seriously affected by smoke, soot, and the deafening noise from trains and engines which renders a great many train-sheds very objectionable. In fact, a

system of platform roofs on the longitudinal platforms, connecting at head-stations directly with the lobby or covered crosswalk in front of the head-house, and at side-stations by means of covered transverse arcades with the platform in front of the depot building, can be considered as far superior to the attempt to build a small and especially a low train-shed, in which the light and ventilation is bad, the smoke and soot a constant annoyance, while the acoustic properties are such that the noise of escaping steam from cylinders or safety-valves, the ringing of the bell, the sounds accompanying the slipping of the drivers in starting a heavy train, combined with the general confusion and bustle, all intensified by the reverberations caused by a low roof and side galleries, render the structure a nuisance to the traveling public, as well as a serious drawback to the quick and efficient despatch of the station service, where dependent on verbal communications or signals by sound. To obtain the best acoustic results a good height of the structure is most valuable, as also the absence of the side galleries or low lean-to roofs on the sides of the main shed span, which are liable to catch the sounds more readily and intensify them by repeated reverberations.

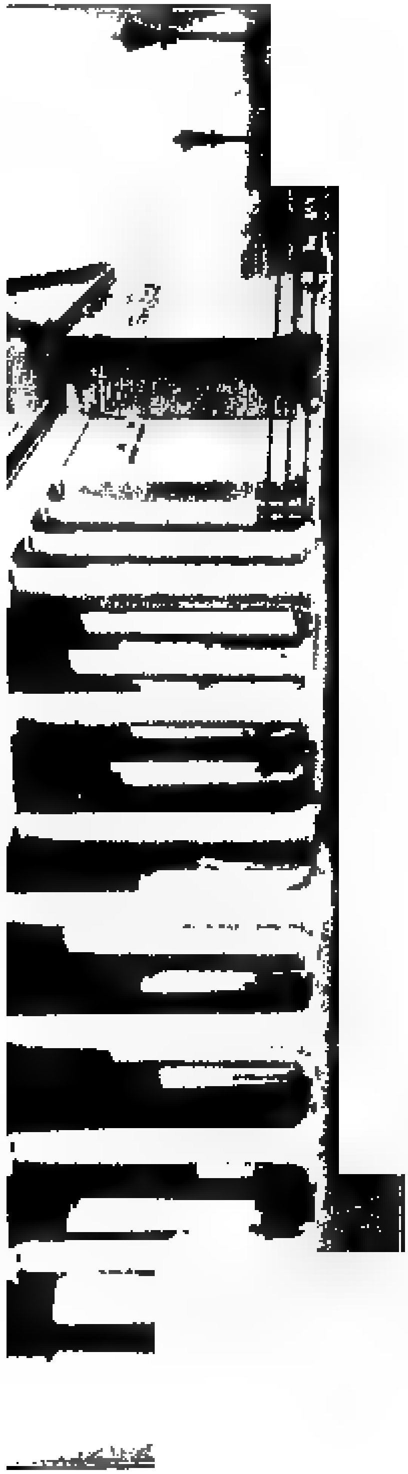
Train-sheds are usually built with iron roof-trusses resting on stone or brick side walls or on iron columns, covered with boards on wooden rafters or purlins, and roofed with tin or tarred felt or building-paper. The exposure of so much iron-work to the deteriorating effects of the sulphurous gases collecting under the roof is very objectionable. Skylights are very hard to keep watertight in consequence of the constant damage being done by these gases. It can, therefore, be said, that practically repairs are constantly required in a large train-shed, if

painting is included; in fact, it is very seldom that painting or repair work of some kind is not going on inside or outside of a train-shed. For this reason prominent railroad men have frequently expressed it as their opinion that the general adoption of iron for train-sheds cannot be considered as such an excellent innovation, as a heavily timbered roof or a combination roof has some decided advantages over an all-iron roof. The roof-trusses in train-sheds are usually spaced from 20 to 40 feet apart. The longitudinal and sway bracing is very important so as to resist the wind-pressure.

Mr. L. C. Fritch, in "Railway Organization and Working," thus describes the passenger terminals at Washington, Boston and St. Louis:

"The new Union Station, Washington, D. C., is intended to be, it is said, the finest railway station in the world (was in course of construction when in 1906 he wrote). The estimated cost is about $18,000,000, shared by the railways, the federal government and the District of Columbia. The train-shed will be 760 feet wide and 705 feet long, and will contain 33 tracks, of which 13 will lie on a lower level than the remaining 20, the former being through-tracks to accommodate the service which will use the tunnel under Capitol Hill. The general waiting-room will be 130 by 220 feet, and will be covered by a Roman barrel-vault 90 feet high. The passenger concourse, or lobby, will be 760 feet long by 130 feet wide, and will be divided into an outbound concourse, 80 feet wide, and an inbound concourse 50 feet wide.

"The Union Station at St. Louis has, perhaps, a larger number of railways using it than any other station in the world. This station was remodeled in 1904 for the traffic arising from the Louisiana Purchase Exposition, which



New Burlington Passenger Station at Omaha, Neb.

was handled with great success. The train-shed is a pocket-shed, 601 feet wide and 810 feet long, and has 32 tracks. The passenger concourse is 120 feet wide—70 feet wide for outgoing and 50 feet wide for incoming passengers. The entrance to the train-shed provides for two three-track Y-connections from each direction. The express buildings are all located alongside and west of the track approaches to the station, each building being provided with independent track connections. The baggage-room for small baggage is located alongside the concourse, but the baggage-room for wagon baggage is located under the south end of the train-shed. Subways are provided for handling baggage and express, and communication with the platform in the train-shed is had by means of elevators.

"The passenger station of the Boston Terminal Company has the unusual feature of a substation located under the main station for the purpose of handling suburban traffic. The train-shed is 620 feet long and 620 feet wide, and has 28 train-tracks. The substation has a double track, spread at the platforms. The substation tracks are entirely below the grade of the surface tracks. The inbound baggage-room is located on the east side, and the outbound baggage-room on the west side, of the train-shed, with a subway for handling both express and baggage. The express buildings are located on the west side of the tracks approaching the station, the buildings being provided with independent tracks for express-cars."

The subject of railway buildings is of too broad a scope to be comprehensively covered here. The large volume by Mr. Berg (already referred to) gives minute descriptions of Passenger Terminals, illustrations and

specifications, and treats of the construction of every kind of building required by railways. Those desiring to go into the subject in detail will find it a valuable work.

The provision for ample track facilities and proper arrangement of tracks at terminals if not of equal importance, is only second to that of Stations, concerning which Mr. L. C. Fritch, in "Railway Organization and Working," says:

"There are two varieties: (1) through-track arrangement, where trains enter at one end of the train-shed and depart from the opposite end; (2) pocket or spur-track arrangement, where trains enter and depart from stub or spur-tracks. The through-track arrangement is the most desirable from every point of view, as it obviates the undesirable feature of backing trains into or out of a terminal station, which must be done in the case of a pocket arrangement. Location and available space often limit the design, or modify it to the extent of permitting only a pocket arrangement, or a modification of it in the form of a combination of a through and pocket arrangement."

Continuing he says:

"Passenger-coach and equipment yards are usually divided into two parts: (a) a coach storage-yard, where coaches and other passenger equipment are stored ready for use, being 'made up' or switched in the order in which the equipment is required for use in trains; (b) a cleaning-yard, where the equipment is placed immediately after arrival, to be cleaned and made ready for use. The storage-yard is usually a simple series of parallel tracks of capacity to hold a train of maximum size; the tracks being, in some instances, designed to

(Patented)
Vacuum Machine, Central Railroad of New Jersey Plant, Communipaw, N. J. Two Steam Driven, Double Cross Connected Engines for Cleaning Passenger Coach and Pullman Equipment.

serve also as a cleaning-yard, where cars may be cleaned without taking them to a separate cleaning-yard.

"The Cleaning-yard is a specially designed yard, with tracks spaced a sufficient distance apart to permit the cleaning of the outside of cars on adjoining tracks. A system of water, air-heater, and gas-pipes extends throughout the yard, with frequent connections so arranged that use may be made of any of these necessities for any car. The renovation of the passenger equipment forms a most important part in the passenger service of today. At the end of each trip or run it is now customary thoroughly to renovate both the interior and the exterior of each passenger-car, entailing a large force of men and no small expense. In this work the vacuum system of cleaning by means of compressed air is now largely employed, resulting in great economy and in increased facility in producing sanitary results. The cost involved in the use of the compressed-air system is about one-half of that of the old method of cleaning.

"Freight Yards, at terminal or for any large freight station, should," Mr. Fritch says, in continuing his subject, "include the following: (1) Freight-yards for the purpose of receiving, classifying, storing, and forwarding the freight-cars; also the necessary appurtenances, such as repair-yards, engine roundhouse, and equipment to care for freight locomotives. (2) Freight Stations, including freight-houses, transfer-houses, warehouses, elevators, platforms, etc., for receiving, delivering, storing, transferring, etc., freight to and from cars. (3) Team-tracks, for the purpose of handling freight directly to and from wagons and cars. (4) Industry tracks, for the purpose of receiving and forwarding freight directly from and to industrial plants; the tracks extending into

Application of Vacuum Cleaner to Railroad Car Seats.

such plants, thus eliminating the necessity of drayage or transfer of freight by wagons. (5) Water terminals, for the purpose of interchange of freight between rail and water-craft; including docks, wharves, piers, elevators, warehouses, etc."

He briefly describes the facilities required under group No. 1, and then, continuing, says:

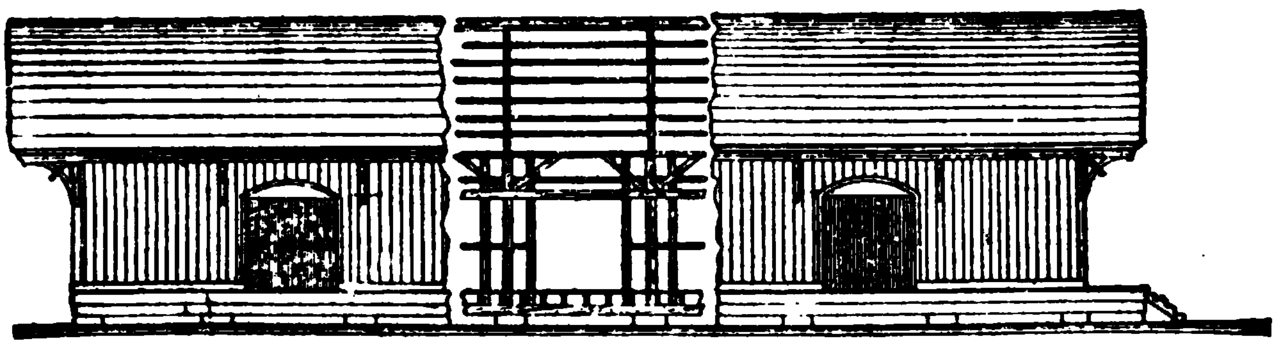
"The summit or hump-yard has become a necessity in a modern large freight-yard, where a heavy volume of business is done. The classifying-yard is usually the limit of the capacity of the entire system. In the design of the summit or hump-yard great care must be exercised to adopt a gradient that will carry cars the necessary distance into the classifying-yard.

"The number of tracks required in a classifying-yard depends upon the number of classifications to be made. The yard of the Chicago Union Transfer Company at Chicago has 42 tracks, of 60 cars' capacity each. The length of the tracks depends upon the maximum number of cars usually handled per train, and ranges from 45 to 90 cars. Track-scales are usually located on the summit or hump."

"*Freight Stations.*—A modern freight station of large dimensions includes such facilities as freight-houses, transfer-houses, warehouses, elevators, platforms, stock-pens, etc., and is used for the purpose of receiving and delivering freight by the railway from and to the public. Certain fundamental principles have been evolved, and are now generally accepted in the establishment of modern freight-station facilities.

"Freight-houses usually consist of inbound and outbound houses. At the inbound house incoming freight is received, being unloaded directly into the house from

tracks along the side. Usually not more than two tracks are required, the unloaded cars being pulled to be replaced with loaded ones. The object of this restriction of the number of tracks is to reduce the distance that freight must be trucked from the cars to the house. Modern practice limits the width of inbound freight-houses from 60 to 70 feet, the length varying with the requirements, regulated by the volume of traffic. It is customary to provide a platform 8 to 10 feet wide on one



Front Elevation.

or both sides of the house, which permits cars to be placed at any point opposite the house, and also furnishes accommodation for the maximum number of wagons on the delivery side of the house. Paved drive-ways, not less than 50 feet wide, should be provided on this side of the house. The doors of the house should be placed uniformly 40 feet center to center, in order to come approximately opposite the car doors when the cars are placed at the house. The house is usually posted in a systematic manner into sections numbered or lettered, and when freight is unloaded, notations are made on the freight-bills showing location, in order that it may be readily located.

"The outbound house is used for the purpose of forwarding shipments received from wagons delivering at

one side of the house. The freight is weighed as received, and then trucked directly into the outbound cars on tracks along the other side of the house. The modern practice is to limit the width of the outbound house to 30 or 35 feet, in order to reduce the trucking distance over which the freight must be handled. The tracks are placed alongside of the house on the side opposite the driveway. They are usually spaced closely together, and as many tracks are provided as the number of cars' capacity for the daily loading requires. It is customary to provide an outside platform on the track side for convenience in longitudinal trucking, but the wagon, or receiving, side is usually provided with a line of doors closely placed, so that nearly the entire side of the house is open for receipt of freight.

End Elevation and Cross-Section.

"Whenever space permits, it is good practice to place the inbound and outbound houses opposite each other, with the tracks between the houses and a transfer platform between two sets of tracks for the purpose of transferring cars. This arrangement is a flexible one, to the extent that the track arrangement can be utilized for either house to any desired limits; also, the transfer freight can be handled at the same time with the inbound and outbound freight. Furthermore, the freighthouse

forces are easily interchangeable, and full advantage can be taken of the fact that in the morning the inbound freight is heavy and the outbound freight light, which conditions are reversed in the afternoons, thus keeping the forces uniformly engaged during the entire day.

"Warehouses are usually provided for the purpose of storing freight, both inbound and outbound; but the regular business of warehousing is one apart from transportation, and in many states the laws prohibit railways from doing a warehouse business, other than such as is incidental to the transporting of the goods. Warehouses are therefore not essentially a part of railway terminal facilities, when considered strictly as warehouses.

"Elevators are provided for handling grain for the purpose of storage, cleaning, clipping, drying, sorting, or transferring from cars to vessels. The usual type, almost a universal one, is a system of tracks constructed over pits into which the grain is unloaded, thence being carried into bins by means of conveyors. Chutes are provided for loading cars on the same tracks when grain shipments are outbound. Marine conveyors are provided for carrying the grain from elevators to vessels, when the elevators are located at a point removed from the vessels' landing. In case of elevators directly alongside of vessels, chutes are used."

WRECKS.

The illustrations accompanying this chapter, together with the directions to trackmen by Mr. Kindelan, as given by him in "The Trackman's Helper," covers what is required of a wrecking gang. A wrecking outfit is usually kept in readiness at each division headquarters

Fig. 93. 35-TON STEAM WRECKING CRANE.

Unusual stability is obtained by the powerful steel jack-arms which are hinged to base of A-frame. These jack-arms extend to a lateral base of 19 feet and are arranged to fold up when not in use. The car is also provided with two additional jacks and four rail clamps. Ample stability is obtained for all ordinary loads by means of jack-screws and rail clamps. It is only necessary to let down the jack-arms when heavy loads are to be lifted and swung to the side. For the lifting of the maximum load in extreme side positions, it is necessary to still further anchor the machine by means of side guys to the top of A-frame, and ring bolts are provided in the head for this purpose.

consisting of a tool car and derrick car. The following list of tools comprises those generally required and in addition most roads use a powerful steam wrecking crane as shown in illustration.

Tools on a wrecking or tool car:

Heating stove.
Hand saws.
Axes.
Adzes.
Wheel gauge.
Steel wrenches.
Soft and chipping hammers.
Track shovels.
30-inch steel bars.
12 torches.
Scoop shovels.
Pinch bars.
Cold chisels.
Clevises.
4 pairs rubber boots.
Pair patent frogs.
Iron bound wedges.
Red flags.
Red, white and green lanterns.
Oil and waste for packing.
16-foot ladder.
Assorted sizes drift bolts.
Coupling links and pins.
8-inch and 12-inch pony jacks.
Standard frogs.
Switch chains.
Torpedoes.
Portable stretcher.
2 gallons alcohol.
Packing hooks and spoons.
12 grain sacks, 2-bushel.
Water barrel.
Cross cut saws.
Hand axes.
Sledge hammers.
12 and 15-inch monkey wrenches.
Spike mauls.
4 inch rolling line.
Picks.
1 pair of climbers.
6 baskets (grain) 2 bushels
6 Water pails.
Standard journal brasses for foreign cars.
2 Hydraulic lifting jacks, 15 and 20 tons.
2 Ratchet lifting jacks and levers.
A few hundred feet of spare 1-inch to 2½-inch guy lines and snatch blocks.
A small coil of telegraph wire and a few insulators and other telegraph supplies necessary to start an emergency office.
A full set of edge tools, the personal property of the foreman of the wrecking crew.

Tools on the derrick car:

1 truck line, 2½ inches diameter, 250 feet long.
1 truck line, 2½ inches diameter, 200 feet long.
2 second-hand steel rails.
4 iron-bound wedges.
6 switch chains.
3 truck chains.
2 wire cables, 1¼ inches diameter.

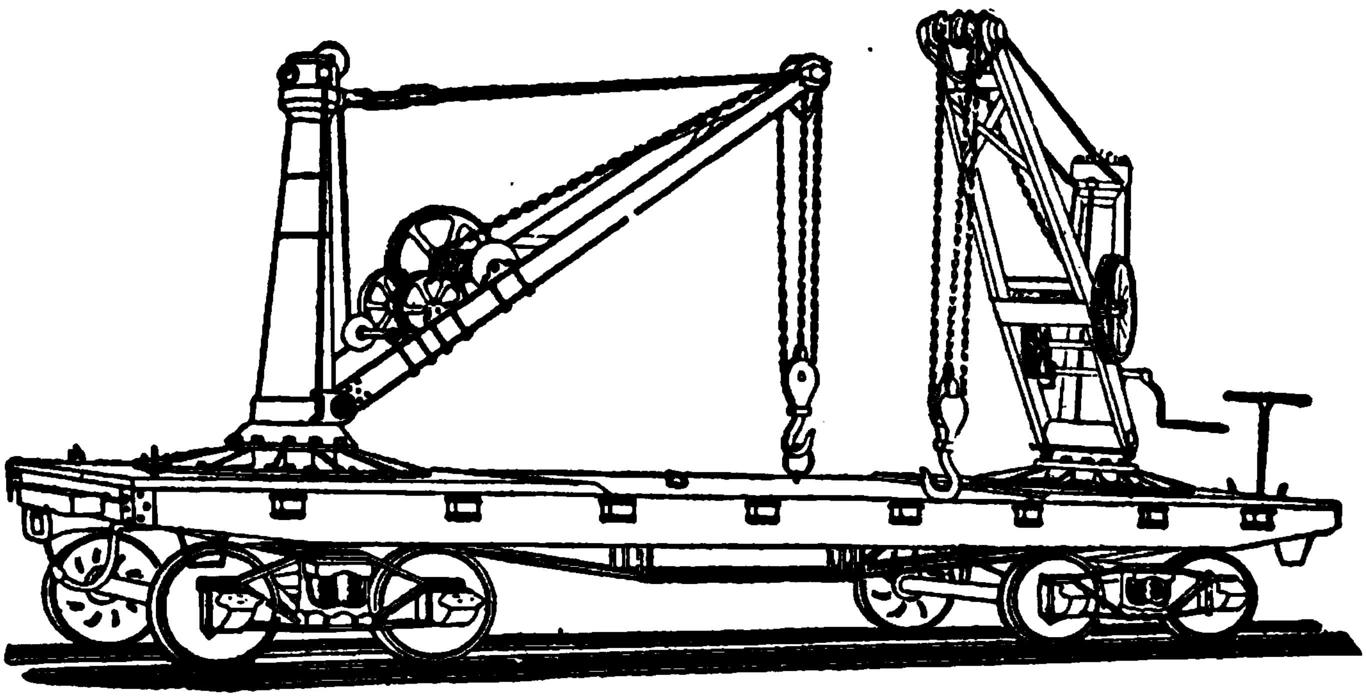


Fig. 94. 15-Ton Double Mast Hand Wrecking Crane.

"When a track foreman arrives at the scene of the accident he should proceed immediately to do whatever work, in his judgment, would contribute most to putting track in a passable condition for other trains, notwithstanding the absence of his superior officers, who may not be able to reach the wreck for several hours. If the track is torn up and the cars do not interfere, put in ties enough to carry a train safely over where you can. If the rails are bent out of shape secure some from near by if it is possible. If this cannot be done, get as many as possible of the damaged rails to their proper shape and spiked down in the track.

"If a small bridge or culvert has given way, crib it up with ties until you can cross it with track. If you cannot procure the ties along your section and many are not needed, remove a part of the ties from the track where it is full tied and where it will leave a sufficient number in the track to make it safe for the passage of trains.

"In the same manner if you are short of bolts and spikes and too much time would be lost by going after them, borrow some from track where they can be spared and fix track to let trains pass.

"If one or both trucks beneath a car should leave the track at once and turn across it as is often the case, uncouple from car and hitch a switch rope to the corner of the truck and to the draw-head of the car next to the one which is off the track. Then pull the truck into a position parallel to the track, after which it can be put on the rails with the wrecking frogs.

"If the car should be loaded very heavily, it might be advisable to raise the end with jacks before squaring the truck. If the right man undertakes this job, the train need not be delayed over thirty minutes.

"Sometimes when a car leaves the track, the center pin breaks or is so badly bent that it cannot be used again. This often happens on the road where there is nothing at hand to remove the crooked pin. In such a case, if the car is empty or not heavily loaded, it is best to roll the truck from beneath the car off the track, and haul the car into the station carefully supported on that end.

"When the ends of a broken center pin do not project the end of a car can be jacked up, the truck placed in position, and the end of the car again allowed to rest in

its place on the truck, after which, if watched carefully, the car can be hauled a long distance.

"It often happens that a car gets off the track in such a place that it is impossible to get the help of an engine to pull it on again without considerable delay. When a case of this kind occurs and there are other cars on the track near by, take the car nearest to the one off the track and couple the two together with a

Fig 95. Tilden Wrecking Frog.

chain or rope long enough to give plenty of slack. Then get together what men are available and push the car which is on the track close to the wrecked car. When you are ready to pull the wrecked car up on the track, start the car which is coupled to it away from it as fast as the men can push it. The jerk, when the slack of the line is taken up, will pull the car on the track as well as an engine can do it. If you have men enough, use for the motive power two or more cars if necessary. This is what is called 'slacking a car onto track.'

"When cars have got off the track and are still on the ties, it is best to put blocks or ties between those in the track to keep the wheels from sinking between the ties. By doing this at once before attempting to put the cars back on the track, will generally save considerable time and labor.

"If an engine or car mounts the outside rail of a sharp curve, and persists in running off the track, oil the rails thoroughly where the most trouble is experienced. This will generally allow the engine or car to go around the curve without leaving the track.

Fig 96. Palmerton Wrecking Frog.

"Very rusty rails on a curve track which has not been used for some time, often cause the wheel to mount the outside rail of a curve, the surface not being smooth enough to allow the wheels to slide.

"If at any time you find the connecting rod of a stub switch broken, or you want to use the switch and have no switch stand, slip a car link between the ends of the lead rails, allowing enough of it to project to hold

the ends of the moving rails in place, or take a piece of plank of the right shape and use it in the same way as the link. This is better.

"When the car trucks are thrown some distance from the track in a wreck, the quickest method of putting them on the track again if you have no derrick car, is to take bars and turn them almost parallel to the track, but with one end a little closer to the track than the other. Hitch a rope to this end of the truck and to the engine or the nearest car which is coupled to the engine, and the truck will pull onto the track easily, if there is nothing to obstruct its passage.

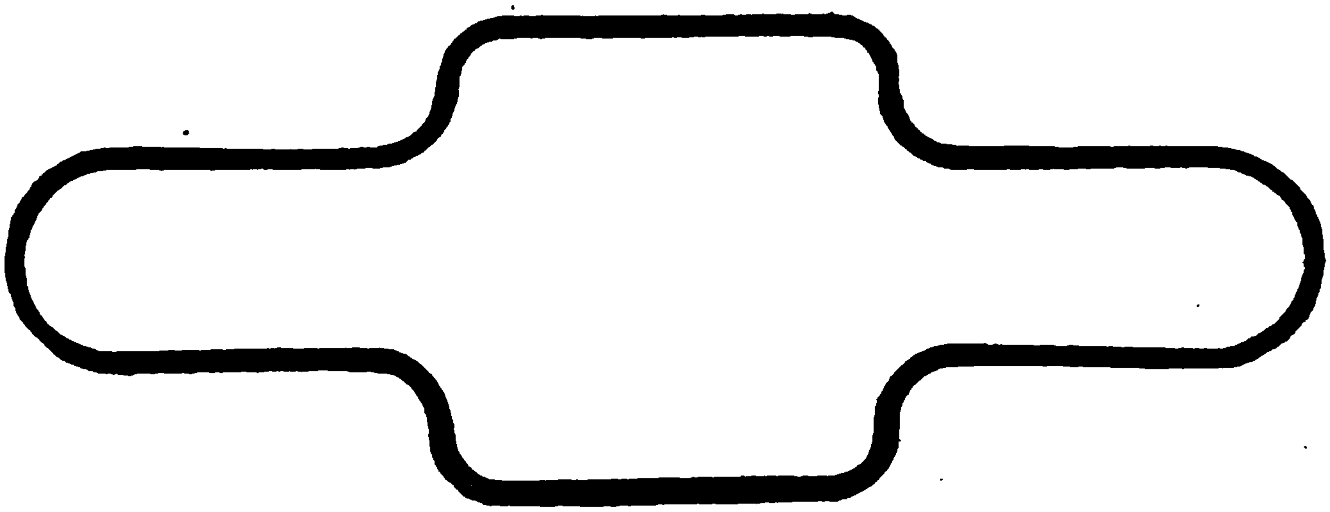


Fig. 97. Device for Splicing a Broken Chain.

"A link made of iron or steel and fashioned after the pattern shown in Fig. 97 is very handy to have when at a wreck pulling cars or engines with a chain. If a chain breaks the two broken ends can be brought together, and fixed in this link as if held with a grab hook.

"When car trucks are sunk in soft ground at a wreck, and there is no derrick car or other lifting apparatus at hand, a good way to handle them is to place a tie cross ways in the ground about four or five feet from

the truck, then place two more long ties or timbers with their centers resting across the first tie and their ends in front of the truck wheels. The truck can then be pushed up on top of the long ties as if on a track. When it is centered over the bottom tie, the truck can be easily turned to run in any direction.

"Trackmen in charge of a ballasting outfit if they are new in the business are often at a loss to know the quickest way to put a plow back on the cars if it should accidentally be pulled off on the ground. The best way to do in such a case is to roll the plow or pull it with the engine and cable into the same position on the track that it would occupy on the cars; then raise up the snout of the plow until you can back the end of a car under it, hook the end of the cable to the plow, block the car wheels and pull the plow on to the car with the engine.

"If the hind truck of any kind of a car should by accident be derailed, broken or rendered useless, the car should be taken to the next station by uncoupling it from the cars behind it. Remove the disabled truck from the track; then take the caboose jacks and raise the body of the car enough to slip a tie under it across the track rails; let the car down upon the tie, and by running carefully the car can be hauled to the station or side track, sliding on the tie.

"It is always best when a wrecked car is loaded, to remove the load, or transfer it to another car on the good track. Outfits starting to go to a wreck should provide themselves with all the tools and appliances necessary for this purpose.

"Car-truck center-pins which have been twisted or broken in a wreck may be removed by going inside the

car and cutting away with a hammer and cold chisel the iron ring which forms the head and shoulders of the pin. The pin may then be driven down through the bottom of the car.

"There should always be a man on hand at a wreck to look after such jobs, and promptly remove all brake-beams, hanging irons, etc., so as not to delay the work after the cars are picked up or ready to be put on the track.

"When pulling on a chain or rope with a locomotive at a wreck care should be taken not to have too much slack, as chains break easily. The same is true of switch ropes, but when they are new or not much worn, they will stand a greater slack strain than a chain will. Wire cables are preferable to either a chain or a rope for pulling, and they will stand a much greater slack strain, if not allowed to become twisted out of shape.

"There is always danger of chains or switch ropes breaking when engines are pulling on them at a wreck, and those working near should not be allowed to stand too close to them.

"What is generally termed 'a dead man' is a device sometimes used to anchor a guy or stay rope where wrecking cars, engines or derricks have to do very heavy hoisting or pulling. It is made by digging a trench five or six feet at a proper distance from the track and parallel to it. A narrow cross trench is then dug, slanting upward from the bottom and middle of the first trench to the surface of the ground. A good track tie or heavy timber is then buried in the first trench, and the rope is passed down through the cross trench and secured to the timber."

In this connection, in speaking of the bridge force and

Fig. 97A. Sketch Showing Methods of Removing Debris, Preparatory to Bridging Openings at Wrecks or Washouts.

wrecks, Mr. Foster says, in his work on Wooden Trestle Bridges: "The quickest method to adopt is to use a locomotive and hauling lines, which is illustrated by Fig. 97A. If this method be adopted, the necessary snatch-blocks may be anchored to what are usually termed 'dead-men,' properly planted in the ground or anchored to trees if any be found convenient. The anchor usually adopted is the 'dead man,' which consists of a piece of timber about 10 x 12 in. x 10 feet in length set horizontally in a trench about 5 feet deep and parallel to the center line of main track, at a sufficient distance from the wreck to haul out cars, trucks, etc., far enough to clear the site of the temporary work. Commencing at the center of the trench already dug, dig another at right angles to it, and about 10 feet long, and sloping from the bottom of original trench to surface of ground toward the wreck. Pass a good one-inch chain around the center of the timber of sufficient length to lead up to the top of the ground. To this chain attach a snatch-block. Another anchor of the same kind should be placed in the ground near the track, to lead the line in the proper direction so it can be attached to the road engine, as illustrated in Fig. 97A.

"After the wreck has been cleared away the bridge force can proceed with the construction of the temporary structure. The character of the structure will depend upon the physical features of the country and the break. The methods usually employed are to build either a pile or framed trestle or cribbing. Where an embankment is side-washed other methods are sometimes adopted. One is to dig down the remaining embankment and bring up the part washed to a level. If the fill is cut down much below the grade, it becomes

necessary to make a long run-off so that the grade will not be too steep. Another way is to build what is called a shoofly around the break. This method is not advisable except in extreme cases, as the cars are likely to run off the track or the train break in two on account of sharp curves and steep grades.

"Where cribbing is employed ordinary track-ties may be used for building the cribs. This is a crude method of constructing temporary work, and is frequently built by men of little experience in construction work of any kind, and consequently is likely to give trouble. Where the cribs are built in a proper manner there is no reason why they should not be perfectly safe. The cribs should be brought up as nearly level as possible, care being taken to select ties of the same thickness for the same courses of a crib. For cribs 6 feet to 8 feet high single cribs may be used, but for higher work the method shown in Fig. 97B makes a firmer structure, with less swaying than double cribs built separately. The cribs should be capped, and the floor-system built with ties and stringers as in other temporary work. Where the bottom is soft a complete floor of ties under the cribs may be necessary to give a proper footing. This method of bridging a break in the track is the most expeditious, as a number of cribs can be built at the same time, and in this way a large force of men can be worked to advantage."

Continuing, Mr. Kindelan says: "The first thing to do with a wrecked engine, if the frame is good, is to take jacks and put the engine in an upright position, such as it would occupy if standing on the main track. It may then be blocked up and raised sufficiently to place under it rails and ties, forming a temporary track. The

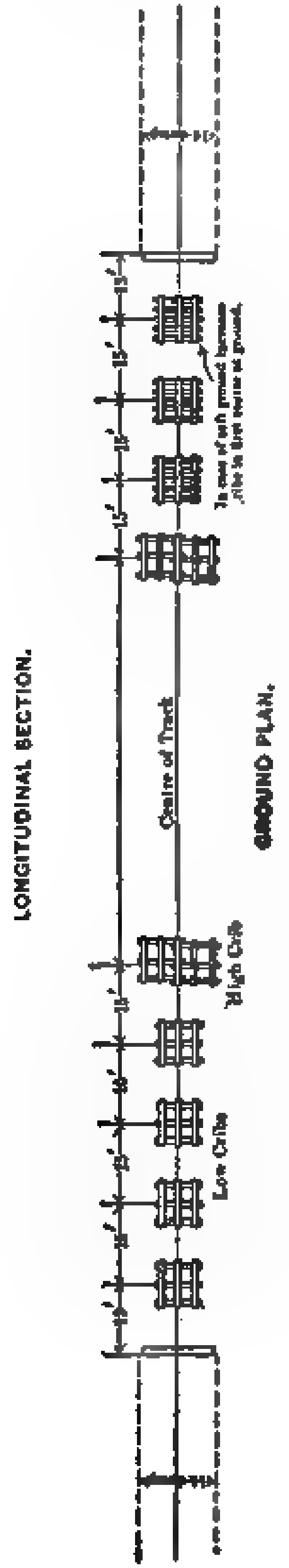


Fig. 97B. Sketch Showing Method of Bridging a Washout with Cribs of Track Ties.

main track should then be cut at a rail joint, and lined out in an easy curve until the ends of the rails are in line with the temporary track. The tracks should then be connected, and the engine pulled upon the main track. If the engine stands at such an angle as to require a very sharp curve in the track over which it is pulled, put plenty of oil on the track rails, and elevate the outside rail of the curve.

"If the engine is only off the rails and still on the track ties, additional rails may be spiked down to the ties in front of the wheels like a switch lead, and connected with a pair of the track rails. The engine may be pulled on again over this lead and the main track closed. This method is quicker and better for putting a derailed engine on the track when more than one truck is off the rails, than using frogs or blocking.

"The first thing to do at any wreck of importance, where cars block the main track, is to use the first locomotive which can be put into service and with switch ropes pull clear of the tracks all cars, trucks or other wreckages which cannot be readily put back on the track with the facilities at hand for doing such work. Proper care should be taken, in doing this part of the work, not to injure freight in the cars. When necessary, remove it from the wrecked cars to a place of safety, and pull the cars and trucks into a position alongside the track, where it will be handy for the wrecking car to pick them up after it arrives.

"The moment the track is clear of wreckage, the track force should go to work and repair it, and quickly put it in good condition for trains.

"Track foremen should not allow their men to become confused or mixed up with the other gangs of men

which are present at a wreck, except when it is necessary for more than one gang of men to work together; even then the foreman should keep his own men as much together as possible, so as to always be able to control their actions and work them to the best advantage.

"No matter what part of the work at a wreck a foreman is called upon to do, he should act promptly, and work with a will to get the wreck cleared up, and the track ready for passage of trains with as little delay as possible."

APPENDIXES.

INDEX TO APPENDIXES.

APPENDIX A.

The subject of curves has been fully covered in this volume by Mr. Stephens, nevertheless, the following tables taken from "The Engineer's Field Book," by Mr. C. S. Cross, may, it is hoped, be of interest and value, and, perhaps, in some instances, serve to supplement the methods already described.

In any event, they may serve for purposes of comparison.

RAILROAD CURVE TABLES BY C. S. CROSS FOR EXPEDITIOUSLY DETERMINING THE POINTS AT WHICH TO COMMENCE THE CURVING.

The following tables compiled by Mr. C. S. Cross show the distance from the point of intersection of the tangent lines to the beginning of one degree curve, the angle of deflection (=angle at center) being known.

In the columns, under the head of degrees and opposite the minutes, are given the distances in feet from the intersection of tangents to the beginning of one degree curve.

To ascertain the distance for any given degree of curve, divide the distance given in the tables for a one degree curve, by the degrees of the required curve, and you have the distance from the point of intersection to the beginning or end of curve.

EXAMPLE.

Required the distance from the point of intersection of tangents to the beginning of a two degrees curve, the angle of deflection being 25°.

In the tables under 25°, and opposite 0′, find 1270.28 which divided by the degrees of the curve (2°) give 635.14 feet, the required distance.

According to Mr. Cross, the radius of a one degree curve is 5730 feet. The circle being divided into 360 parts of one degree (equal angle of deflection) give 360 chords of one foot in length at the circumference, and also a radius of 57.3 ft.

$$\frac{360}{3.1416}=\frac{114.6}{2}=57.3$$

The chord of one foot in length for 1 degree=57.3 ft. radius.

The chord of 10 feet in length for 1 degree =573.0 ft. radius.

The chord of 100 feet in length for 1 degree =5730.0 ft. radius.

Or the radius may be calculated by natural sines, thus:

sin. 1° : 100 ft. chord : sin. 89° 30′ : 5730 ft. radius.

To determine the degree of curvature, having the radius given, divide the radius of a one degree curve, 5730, by the radius of the given curve.

EXAMPLE.

Required the degree of a curve having a radius of 1000 feet:

$$\frac{5730}{1000}=5.73^\circ=5^\circ\ 43'\ 48''$$

To determine the length of the curve having the angle of deflection given; divide the angle of deflection (=angle at centre) by the degrees of the curve, and you have the required length of the curve. If there are degrees and minutes in the angle of deflection, the minutes should be converted into decimals.—(*See Table*).

EXAMPLE.

The angle of deflection being 20° 49′, $\frac{49}{60} = 0.816$. Then 20,816 is the distance for a one degree curve; if for a 2 degree curve, divide this result by 2; for a 3 degree curve, divide by three, and so on.

The angle of deflection being given, the following results are readily determined.

Angle of deflection.	Degree of curve.	Deflection per 100 feet.	Radius of curve.	Distance from intersection to beginning of curve.	Length of curve.
20° 49′	1°	0° 30′	5730.	1052.49	2081.6
20° 49′	2°	1° 00′	2865.	526.24	1040.8
20° 49′	3°	1° 30′	1910.	350.83	693.8
20° 49′	4°	2° 00′	1432.5	263.12	520.4
20° 49′	5°	2° 30′	1146.	210.50	416.3

To ascertain the radius of a curve, having the angle of deflection, and the distance from intersection to beginning of curve given. Find the distance for the angle of deflection in the tables, which divided by 5730 gives the natural tangent of half the angle.

Then divide the distance from intersection to beginning of curve by the natural tangent of half the angle, and you have the radius.

EXAMPLE.

Required the radius of a curve, the angle of deflection being 20°, and the distance from intersection of tangents to beginning of curve 225 feet.

Under 20° and opposite 0′ in the tables, find 1010.37, which divided by 5730 feet gives the natural tangent 0.17633. Then 225 ft. divided by 0.17633 gives the radius 1276 feet.

NATURAL TANGENTS.

Mr. Cross says further: "From the tables may also be determined the natural tangent for any given number of degrees and minutes from one degree to 45°, by taking the distance given in the tables for twice the angle of which the tangent is sought, and dividing the same by 5730."

EXAMPLES:

1st. Required the natural tangent of 30°. Under 60° (twice the angle) find in the tables 3308.21 and divide the same by 5730, and you have the natural tangent for 30°=0.57735.

2d. Required the natural tangent for an angle of 7° 28′; in the column of distances under 14° and opposite 56′ (twice the angle) find 750.97, which divided by 5730 gives the natural tangent for 7° 28′=0.13106.

"When a 66 foot chain is used for the length of stations, the radius of a one degree curve, 5730 feet, may represent 57.30 chains of 66 feet, and the distances in the tables applied the same as for chains of 100 feet in length; but the radius as well as the length of stations will be proportionally less than for stations of 100 feet in length by 1/34 part."

"If a 66 foot chain is used, the distance after being found in the tables, may be divided by 66, and the stations in the curve reduced to 75.76 links which are equal to 50 feet, one-half the length of the stations generally adopted in staking the center line of railroads; and the curve staked out accordingly, turning off one-half the number of degrees required for the stations of 100 feet in length."

"The degree of curvature is understood to express the number of degrees per 100 feet, and hence the convenience of making the stations of such length as will give a definite idea of the degree of curve and length of radius."

′	13°	14°	15°	16°	17°	18°	19°	20°	21°	22°	23°	24°	25°	′
0	652.87	703.53	754.35	805.29	856.35	907.52	958.86	1010.37	1062.00	1113.80	1165.76	1217.96	1270.28	0
1	653.71	704.38	755.20	806.14	857.20	908.38	959.72	1011.23	1062.86	1114.67	1166.63	1218.83	1271.16	1
2	654.56	705.23	756.05	806.99	858.05	909.23	960.57	1012.09	1063.73	1115.53	1167.50	1219.70	1272.03	2
3	655.40	706.07	756.89	807.84	858.90	910.09	961.43	1012.95	1064.59	1116.40	1168.37	1220.57	1272.91	3
4	656.25	706.92	757.74	808.64	859.76	910.94	962.30	1013.81	1065.45	1117.26	1169.24	1221.45	1273.79	4
5	657.09	707.77	758.59	809.54	860.61	911.80	963.15	1014.67	1066.32	1118.13	1170.11	1222.32	1274.66	5
6	657.93	708.62	759.44	810.39	861.46	912.65	964.00	1015.53	1067.18	1118.99	1170.98	1223.19	1275.54	6
7	658.78	709.47	760.29	811.24	862.31	913.51	964.86	1016.39	1068.04	1119.86	1171.85	1224.06	1276.42	7
8	659.62	710.31	761.13	812.09	863.16	914.36	965.72	1017.24	1068.91	1120.72	1172.71	1224.93	1277.29	8
9	660.47	711.16	761.98	812.94	864.01	915.22	966.58	1018.10	1069.77	1121.59	1173.58	1225.80	1278.17	9
10	661.31	712.01	762.83	813.79	864.87	916.07	967.43	1018.96	1070.63	1122.45	1174.45	1226.67	1279.05	10
11	662.15	712.86	763.68	814 64	865.72	916.93	968.29	1019.82	1071.50	1123.32	1175.32	1227.54	1279.92	11
12	663.00	713.71	764.53	815.49	866.57	917.78	969.15	1020.68	1072.36	1124.18	1176.19	1228.42	1280.80	12
13	663.84	714.55	765.37	816.34	867.42	918.64	970.00	1021.54	1073.22	1125.05	1177.06	1229.29	1281.69	13
14	664.69	715.40	766.22	817.19	868.27	919.49	970.86	1022.40	1074.09	1125.91	1177.93	1230.16	1282.55	14
15	665.53	716.25	767.07	818.04	869.12	920.35	971.72	1023.26	1074.95	1126.78	1178.80	1231.03	1283.43	15
16	666.37	717.10	767 92	818.89	869.98	921.20	972.58	1024.12	1075.81	1127.64	1179.67	1231.90	1284.31	16
17	667.22	717.95	768.77	819.74	870.83	922 06	973.43	1024.98	1076.68	1128.50	1180.54	1232.77	1285.18	17
18	668.06	718.79	769.61	820.59	871.68	922.91	974.29	1025.84	1077.54	1129.37	1181.41	1233.64	1286.06	18
19	668.91	719.64	770.46	821.44	872.53	923.77	975.15	1026.70	1078.40	1130.24	1182.28	1234.51	1286.94	19
20	669.75	720.49	771.31	822.29	873.38	924.63	976.01	1027.56	1079.27	1131.10	1183 15	1235.39	1287.81	20
21	670.59	721.35	772.16	823.14	874.23	925.48	976.86	1028.42	1080.13	1131.97	1184.02	1236.26	1288.69	21
22	671.44	722.20	773.01	823.99	875.09	926.34	977.72	1029.27	1080.99	1132.83	1184.88	1237.13	1289.57	22
23	672.28	723.04	773.85	824.84	875.94	927.19	978.58	1030.13	1081.86	1133.70	1185.75	1238.00	1290.44	23
24	673.13	723.89	774.70	825.69	876.79	928.05	979.44	1030.99	1082.72	1134.56	1186.62	1238.87	1291.32	24
25	673.97	724.74	775.55	826.54	877.64	928.90	980.29	1031.85	1083.58	1135.43	1187.49	1239.74	1292.20	25
26	674.81	725.59	776.40	827.39	878.49	929.76	981.15	1032.71	1084.45	1136.29	1188.36	1240.61	1293.07	26
27	675.66	726.44	777.25	828.24	879.34	930.61	982.01	1033.57	1085.31	1137.16	1189.23	1241.49	1293.95	27
28	676.51	727.28	778.09	829.09	880.20	931.47	982.86	1034.43	1086.17	1138.02	1190.10	1242.36	1294.83	28
29	677.35	728.13	778.94	829.94	881.05	932.32	983.72	1035.29	1087.04	1138.89	1190.97	1243.23	1295.70	29

RAILROAD CURVE TABLES.

′	13°	14°	15°	16°	17°	18°	19°	20°	21°	22°	23°	24°	25°	′
30	678.20	728.97	779.79	830.79	881.90	933.18	984.58	1036.15	1087.90	1139.75	1191.84	1244.10	1296.58	30
31	679.04	729.82	780.64	831.64	882.75	934.04	985.44	1037.01	1088.76	1140.62	1192.71	1244.97	1297.46	31
32	679.89	730.66	781.49	832.49	883.61	934.89	986.30	1037.87	1089.63	1141.48	1193.58	1245.85	1298.33	32
33	680.73	731.51	782.34	833.35	884.46	935.75	987.16	1038.74	1090.49	1142.35	1194.45	1246.72	1299.21	33
34	681.58	732.35	783.19	834.20	885.32	936.60	988.02	1039.60	1091.35	1143.22	1195.32	1247.59	1300.09	34
35	682.42	733.20	784.04	835.05	886.17	937.46	988.88	1040.46	1092.22	1144.09	1196.19	1248.46	1300.96	35
36	683.26	734.05	784.89	835.90	887.02	938.32	989.74	1041.32	1093.08	1144.95	1197.06	1249.34	1301.84	36
37	684.11	734.89	785.74	836.75	887.88	939.17	990.60	1042.18	1093.94	1145.82	1197.93	1250.21	1302.72	37
38	684.95	735.74	786.59	837.61	888.73	940.03	991.46	1043.05	1094.81	1146.69	1198.80	1251.08	1303.59	38
39	685.80	736.58	787.44	838.46	889,59	940.88	992.32	1043,91	1095.67	1147.55	1199.68	1251.95	1304.47	39
40	686.64	737.43	788.29	839.31	890.44	941.74	993.18	1044.77	1096.53	1148.42	1200.55	1252.83	1305.35	40
41	687.48	738.28	789.14	840.16	891.29	942.60	994.04	1045.63	1097.40	1149.29	1201.42	1253.70	1306.22	41
42	688.33	739.12	789.99	841.01	892.15	943.45	994.90	1046.49	1098.26	1150.15	1202.29	1254.57	1307.10	42
43	689.17	739.97	790.84	841.87	893.00	944.31	995.76	1047.36	1099.12	1151.02	1203.16	1255.44	1307.98	43
44	690.02	740.81	791.69	842.72	893.86	945.16	996.62	1048.22	1099.99	1151.89	1204.03	1256.32	1308.85	44
45	690.86	741.66	792.54	843.57	894.71	946.02	997.48	1049.08	1100.85	1152.76	1204.90	1257.19	1309.73	45
46	691.70	742.51	793.39	844.42	895.56	946.88	998.34	1049.94	1101.71	1153.62	1205.77	1258.06	1310.61	46
47	692.55	743.35	794.24	845.27	896.42	947.73	999.19	1050.80	1102.58	1154.49	1206.64	1258.93	1311.48	47
48	693.39	744.20	795.09	846.13	897.27	948.59	1000.05	1051.67	1103.44	1155.36	1207.51	1259.81	1312.36	48
49	694.24	745.04	795.94	846.98	898.13	949.44	1000.91	1052.58	1104.30	1156.22	1208.38	1260.68	1313.24	49
50	695.08	745.89	796.79	847.83	898.98	950.30	1001.77	1053.39	1105.17	1157.09	1209.25	1261.55	1314.11	50
51	695.92	746.74	797.64	848.68	899.83	951.16	1002.63	1054.25	1106.03	1157.96	1210.12	1262,42	1314.99	51
52	696.77	747.58	798.49	849.53	900.69	952.01	1003.49	1055.11	1106.89	1158.82	1210.99	1263.30	1315.87	52
53	697.61	748.43	799.34	850.39	901.54	952.87	1004.35	1055.98	1107.76	1159.69	1211.86	1264.17	1316.74	53
54	698.46	749.27	800.19	851.24	902.40	953.72	1005.21	1056.84	1108.62	1160.56	1212.73	1265.04	1317.62	54
55	699.30	750.12	801.04	852.09	903.25	954.58	1006.07	1057.70	1109.48	1161.43	1213.61	1265.92	1318.50	55
56	700.14	750.97	801.89	852.94	904.10	955.44	1006.93	1058.56	1110.35	1162.29	1214.48	1266.79	1319.37	56
57	700.99	751.81	802.74	853.79	904.96	956.29	1007.79	1059.42	1111.21	1163.16	1215.35	1267.66	1320.25	57
58	701.83	752.66	803.59	854.65	905.81	957.15	1008.65	1060.28	1112.07	1164.03	1216.22	1268.53	1321.13	58
59	702.68	753.50	804.44	855.50	906.67	958.00	1009.51	1061.14	1112.94	1164.89	1217.09	1269.41	1322.00	59

RAILROAD CURVE TABLES.

′	26°	27°	28°	29°	30°	31°	32°	33°	34°	35°	36°	37°	38°	′
0	1322.88	1375.65	1428.65	1481.89	1535.30	1589.04	1643.08	1697.28	1751.83	1806.67	1861.79	1917.26	1973.01	0
1	1323.76	1376.53	1429.54	1482.78	1536.20	1589.94	1643.98	1698.19	1752.74	1807.59	1862.71	1918.19	1973.94	1
2	1324.63	1377.41	1430.42	1483.67	1537.09	1590.84	1644.88	1699.10	1753.66	1808.50	1863.64	1919.11	1974.88	2
3	1325.51	1378.30	1431.31	1484.56	1537.99	1591.74	1645.78	1700.01	1754.57	1809.42	1864.56	1920.04	1975.81	3
4	1326.39	1379.18	1432.20	1485.45	1538.88	1592.64	1646.69	1700.92	1755.48	1810.34	1865.48	1920.97	1976.75	4
5	1327.27	1380.06	1433 08	1486.34	1539.78	1593.54	1647.59	1701.83	1756.40	1811.25	1866.41	1921.89	1977.68	5
6	1328.14	1380.94	1433.97	1487.23	1540.67	1594.44	1648.49	1702.74	1757.31	1812.17	1867.33	1922.82	1978.61	6
7	1329.02	1381.82	1434.86	1488.12	1541.57	1595.34	1649.39	1703.65	1758.22	1813.09	1868.25	1923.74	1979.55	7
8	1329.90	1382.70	1435.74	1489.01	1542.47	1596.24	1650.29	1704.55	1759.13	1814.00	1869.17	1924.67	1980.48	8
9	1330.78	1383.59	1436.63	1489.90	1543.36	1597.14	1651.19	1705.46	1760.05	1814.92	1870.10	1925.60	1981.42	9
10	1331.65	1384.47	1437.52	1490.79	1544.26	1598.04	1652.09	1706.37	1760.96	1815.84	1871.02	1926.52	1982.35	10
11	1332.53	1385.35	1438.40	1491.68	1545.15	1598.94	1652.99	1707.28	1761.87	1816.75	1871.94	1927.45	1983 28	11
12	1333.41	1386.23	1439.29	1492.57	1546.05	1599.84	1653.90	1708.19	1762.79	1817.67	1872.86	1928.38	1984.22	12
13	1334.28	1387.11	1440.18	1493.46	1546.94	1600.74	1654.80	1709.10	1763.70	1818.59	1873.78	1929.30	1985.15	13
14	1335.16	1387.99	1441.06	1494.35	1547.84	1601.64	1655.70	1710.01	1764.61	1819.50	1874.71	1930.23	1986.09	14
15	1336.04	1388.88	1441.95	1495.24	1548.74	1602.54	1656.60	1710.92	1765.53	1820.42	1875.63	1931.15	1987.02	15
16	1336.92	1389.76	1442.84	1496.13	1549.63	1603.44	1657.50	1711.83	1766.44	1821.34	1876.55	1932.08	1987.95	16
17	1337.79	1390.64	1443.72	1497.02	1550.53	1604.33	1658.40	1712.74	1767.35	1822.25	1877.48	1933.01	1988.89	17
18	1338.67	1391.52	1444.61	1497.91	1551.42	1605.23	1659.30	1713.65	1768.26	1823.17	1878.40	1933.93	1989.82	18
19	1339.55	1392.40	1445.50	1498.80	1552.32	1606.13	1660.20	1714.56	1769.18	1824.09	1879.32	1934.86	1990.76	19
20	1340.43	1393.28	1446.38	1499.69	1553.21	1607.03	1661.11	1715.47	1770.09	1825.00	1880.24	1935.79	1991.69	20
21	1341.30	1394.17	1447.27	1500.58	1554.11	1607.93	1662.01	1716.38	1771.00	1825.92	1881.16	1936.71	1992.62	21
22	1342.18	1395.05	1448.16	1501.47	1555.00	1608.83	1662.91	1717.28	1771.92	1826.84	1882.09	1937.64	1993.56	22
23	1343.06	1395.93	1449.04	1502.36	1555.90	1609.73	1663.81	1718.19	1772.83	1827.75	1883.01	1938.56	1994.49	23
24	1343.94	1396.81	1449.93	1503.25	1556.80	1610.63	1664.71	1719.10	1773.74	1828.67	1883.93	1939.49	1995.43	24
25	1344.81	1397.69	1450.82	1504.14	1557.69	1611.53	1665.61	1720.01	1774.66	1829.59	1884.86	1940.42	1996.36	25
26	1345.69	1398.57	1451.70	1505.03	1558.59	1612.43	1666.51	1720.92	1775.57	1830.50	1885.78	1941.34	1997.29	26
27	1346.57	1399.46	1452.59	1505.92	1559.48	1613.33	1667.42	1721.83	1776.48	1831.42	1886.71	1942.27	1998.23	27
28	1347.44	1400.34	1453.48	1506.81	1560.38	1614.23	1668.32	1722.74	1777.39	1832.34	1887.63	1943.20	1999.16	28
29	1348.32	1401.22	1454.36	1507.70	1561.28	1615 13	1669.22	1723.65	1778.31	1833.25	1888.55	1944.12	2000.10	29

RAILROAD CURVE TABLES.

′	26°	27°	28°	29°	30°	31°	32°	33°	34°	35°	36°	37°	38°	′
30	1349.20	1402.10	1455.25	1508.59	1562.17	1616.03	1670.12	1724.56	1779.22	1834.17	1889.47	1945.05	2001.03	30
31	1350.08	1402.99	1456.14	1509.48	1563.07	1616.93	1671.03	1725.47	1780.14	1835.09	1890.40	1945.98	2001.97	31
32	1350.96	1403.87	1457.03	1510.37	1563.96	1617.83	1671.93	1726.38	1781.05	1836.01	1891.32	1946.91	2002.90	32
33	1351.85	1404.76	1457.91	1511.26	1564.86	1618.74	1672.84	1727.29	1781.97	1836.93	1892.25	1947.85	2003.84	33
34	1352.73	1405.64	1458.80	1512.15	1565.75	1619.64	1673.74	1728.20	1782.88	1837.85	1893.17	1948.78	2004.77	34
35	1353.61	1406.53	1459.69	1513.04	1566.65	1620.54	1674.65	1729.10	1783.80	1838.77	1894.10	1949.71	2005.71	35
36	1354.49	1407.41	1460.58	1513.93	1567.54	1621.44	1675.55	1730.01	1784.71	1839.69	1895.03	1950.64	2006.65	36
37	1355.37	1408.30	1461.47	1514.82	1568.44	1622.34	1676.46	1730.92	1785.63	1840.61	1895.95	1951.57	2007.58	37
38	1356.25	1409.18	1462.35	1515.71	1569.34	1623.24	1677.36	1731.83	1786.54	1841.54	1896.88	1952.51	2008.52	38
39	1357.14	1410.07	1463.24	1516.60	1570.23	1624.15	1678.27	1732.74	1787.46	1842.46	1897.81	1953.44	2009.45	39
40	1358.02	1410.95	1464.13	1517.49	1571.13	1625.05	1679.17	1733.65	1788.37	1843.38	1898.73	1954.37	2010.39	40
41	1358.90	1411.84	1465.02	1518.38	1572.02	1625.95	1680.08	1734.56	1789.29	1844.30	1899.66	1955.30	2011.33	41
42	1359.78	1412.72	1465.91	1519.27	1572.92	1626.85	1680.98	1735.47	1790.20	1845.22	1900.59	1956.23	2012.26	42
43	1360.66	1413.61	1466.79	1520.16	1573.81	1627.75	1681.89	1736.38	1791.12	1846.14	1901.51	1957.17	2013.20	43
44	1361.54	1414.49	1467.68	1521.05	1574.71	1628.65	1682.79	1737.29	1792.03	1847.06	1902.44	1958.10	2014.14	44
45	1362.43	1415.38	1468.57	1521.94	1575.61	1629.56	1683.70	1738.20	1792.95	1847.98	1903.36	1959.03	2015.07	45
46	1363 31	1416.26	1469.46	1522.83	1576.50	1630.46	1684.61	1739.10	1793.86	1848.90	1904.29	1959.96	2016.01	46
47	1364.19	1417.15	1470.35	1523.73	1577.40	1631.36	1685.51	1740.01	1794.78	1849.82	1905.22	1960.89	2016.94	47
48	1365 07	1418.03	1471.23	1524.62	1578.29	1632.26	1686.42	1740.92	1795.69	1850.74	1906.14	1961.83	2017.88	48
49	1365.95	1418.92	1472.12	1525.51	1579.19	1633.16	1687.82	1741.83	1796.61	1851.66	1907.07	1962.76	2018.81	49
50	1366.83	1419.80	1473.01	1526.40	1580.08	1634.06	1688.23	1742.74	1797.52	1852.58	1908.00	1963.69	2019.75	50
51	1367.72	1420.69	1473.90	1527.29	1580.98	1634.97	1689.13	1743.65	1798.44	1853.50	1908.92	1964.62	2020.69	51
52	1368.60	1421.57	1474.79	1528.18	1581.88	1635.87	1690.04	1744.56	1799.35	1854.43	1909.85	1965.55	2021.62	52
53	1369.48	1422.46	1475.67	1529.07	1582.77	1636.77	1690.94	1745.47	1800.27	1855.35	1910.77	1966.49	2022.56	53
54	1370.36	1423.34	1476.56	1529.96	1583.67	1637.67	1691.85	1746.38	1801.18	1856.27	1911.70	1967.42	2023.49	54
55	1371.24	1424.23	1477.45	1530.85	1584.56	1638.57	1692.75	1747.29	1802.10	1857.19	1912.63	1968.35	2024.43	55
56	1372.12	1425.11	1478.34	1531.74	1585.46	1639.47	1693.66	1748.19	1803.01	1858.11	1913.55	1969.28	2025.37	56
57	1373.01	1425.99	1479.23	1532.63	1586.35	1640.38	1694.56	1749.10	1803.93	1859.03	1914.48	1970.21	2026.30	57
58	1373.89	1426.88	1480.11	1533.52	1587.25	1641.28	1695.47	1750.01	1804.84	1859.95	1915.41	1971.15	2027.24	58
59	1374.77	1427.77	1481.00	1534.41	1588.15	1642.18	1696.37	1750.92	1805.76	1860.87	1916.33	1972.08	2028.17	59

RAILROAD CURVE TABLES.

′	39°	40°	41°	42°	43°	44°	45°	46°	47°	48°	49°	50°	51°	′
0	2029.11	2085.55	2142.33	2199.52	2257.10	2315.09	2373.42	2432.21	2491.46	2551.11	2611.27	2671.90	2733.04	0
1	2030.05	2086.50	2143.28	2200.48	2258.06	2316.06	2374.40	2433.20	2492.45	2552.11	2612.28	2672.92	2734.07	1
2	2030.99	2087.44	2144.24	2201.44	2259.03	2317.03	2375.38	2434.18	2493.45	2553.11	2613.29	2673.94	2735.09	2
3	2031.93	2088.39	2145.19	2202.40	2259.99	2318.00	2376.35	2435.17	2494.44	2554.11	2614.30	2674.95	2736.12	3
4	2032.87	2089.33	2146.14	2203.35	2260.96	2318.97	2377.33	2436.15	2495.43	2555.11	2615.31	2675.97	2737.14	4
5	2033.81	2090.28	2147.10	2204.31	2261.92	2319.94	2378.31	2437.14	2496.43	2556.11	2616.32	2676.99	2738.17	5
6	2034.75	2091.22	2148.05	2205.27	2262.89	2320.91	2379.29	2438.12	2497.42	2557.12	2617.32	2678.01	2739.19	6
7	2035.69	2092.17	2149.00	2206.23	2263.85	2321.88	2380.27	2439.11	2498.41	2558.12	2618.33	2679.03	2740.22	7
8	2036.63	2093.11	2149.95	2207.19	2264.82	2322.85	2381.24	2440.10	2499.40	2559.12	2619.34	2680.04	2741.25	8
9	2037.57	2094.06	2150.91	2208.15	2265.78	2323.82	2382.22	2441.08	2500.40	2560.12	2620.35	2681.06	2742.27	9
10	2038.51	2095.00	2151.86	2209.11	2266.75	2324.79	2383.20	2442.07	2501.39	2561.12	2621.36	2682.08	2743.30	10
11	2039.45	2095.95	2152.81	2210.07	2267.71	2325.76	2384.18	2443.05	2502.38	2562.12	2622.36	2683.10	2744.32	11
12	2040.39	2096.89	2153.77	2211.02	2268.68	2326.73	2385.16	2444.04	2503.38	2563.12	2623.37	2684.12	2745.35	12
13	2041.33	2097.84	2154.72	2211.98	2269.64	2327.70	2386.13	2445.02	2504.37	2564.12	2624.38	2685.13	2746.37	13
14	2042.27	2098.78	2155.67	2212.94	2270.61	2328.67	2387.11	2446.01	2505.36	2565.12	2625.39	2686.15	2747.40	14
15	2043.21	2099.73	2156.63	2213.90	2271.57	2329.64	2388.09	2447.00	2506.36	2566.12	2626.40	2687.17	2748.43	15
16	2044.15	2100.67	2157.58	2214.86	2272.54	2330.61	2389.07	2447.98	2507.35	2567.13	2627.41	2688.19	2749.45	16
17	2045.08	2101.62	2158.53	2215.82	2273.50	2331.59	2390.05	2448.97	2508.34	2568.13	2628.41	2689.21	2750.48	17
18	2046.02	2102.57	2159.48	2216.78	2274.46	2332.56	2391.02	2449.95	2509.33	2569.13	2629.42	2690.22	2751.50	18
19	2046.96	2103.51	2160.44	2217.74	2275.43	2333.52	2392.00	2450.94	2510.33	2570.13	2630.43	2691.24	2752.53	19
20	2047.90	2104.46	2161.39	2218.69	2276.39	2334.49	2392.98	2451.92	2511.32	2571.13	2631.44	2692.26	2753.55	20
21	2048.84	2105.40	2162.34	2219.65	2277.36	2335.46	2393.96	2452.91	2512.32	2572.13	2632.45	2693.28	2754.58	21
22	2049.78	2106.35	2163.30	2220.61	2278.32	2336.44	2394.94	2453.89	2513.31	2573.13	2633.46	2694.30	2755.61	22
23	2050.72	2107.29	2164.25	2221.57	2279.29	2337.41	2395.91	2454.88	2514.30	2574.13	2634.47	2695.31	2756.63	23
24	2051.66	2108.24	2165.20	2222.53	2280.25	2338.38	2396.89	2455.87	2515.30	2575.13	2635.48	2696.33	2757.66	24
25	2052.60	2109.18	2166.16	2223.49	2281.22	2339.35	2397.87	2456.85	2516.29	2576.13	2636.49	2697.35	2758.68	25
26	2053.54	2110.13	2167.11	2224.45	2282.18	2340.32	2398.85	2457.84	2517.28	2577.13	2637.50	2698.37	2759.71	26
27	2054.48	2111.07	2168.06	2225.40	2283.15	2341.29	2399.83	2458.82	2518.27	2578.13	2638.50	2699.39	2760.73	27
28	2055.42	2112.02	2169.01	2226.36	2284.11	2342.26	2400.80	2459.81	2519.27	2579.13	2639.51	2700.40	2761.76	28
29	2056.36	2112.96	2169.97	2227.32	2285.08	2343.23	2401.78	2460.80	2520.26	2580.13	2640.52	2701.42	2762.79	29

OAD CURVE TABLES

4°	45°	46°
1.20	2402.76	2461.78
5.17	2403.74	2462 77
6.15	2404 72	2463 76
7 12	2405 71	2464.75
8.10	2406.69	2465.74
9.07	2407.67	2466.73
0.04	2408 65	2467.72
1.02	2409.63	2468.71
1 99	2410.61	2469.69
2.97	2411.60	2470.68
3.94	2412.58	2471.67
4.91	2413.56	2472.66
5.89	2414.54	2473.66
6.86	2415.52	2474.64
7.84	2416.50	2475.63
8.81	2417.49	2476.62
9.78	2418.47	2477.61
0 76	2419.45	2478.60
1.73	2420.43	2479.59
2.71	2421.41	2480.58
3.68	2422.39	2481.57
4.65	2423.38	2482.56
5.63	2424.36	2483.54
6.60	2425.34	2484.53
7.58	2426.32	2485.52
8.55	2427.30	2486.51
9.52	2428.28	2487.50
0.50	2429.27	2488.49
1.47	2430.25	2489.48
2.45	2431.23	2490.47

RAILROAD CURVE TABLES.

′	52°	53°	54°	55°	56°	57°	58°	59°	60°	61°	62°	63°	64°	′
0	2794.69	2856.86	2919.55	2982.81	3046.64	3111.10	3176.14	3241.86	3308.21	3375.20	3442.93	3511.34	3580.45	0
1	2795.72	2857.90	2920.60	2983.87	3047.71	3112.18	3177.23	3242.96	3309.32	3376.33	3444.07	3512.49	3581.61	1
2	2796.76	2858.95	2921.65	2984.93	3048.78	3113.26	3178.32	3244.06	3310.44	3377.45	3445.20	3513.64	3582.78	2
3	2797.79	2859.99	2922.71	2986.00	3049.86	3114.34	3179.42	3245.17	3311.55	3378.58	3446.34	3514.78	3583.94	3
4	2798.82	2861.03	2923.76	2987.06	3050.93	3115.42	3180.51	3246.27	3312.67	3379.70	3447.48	3515.93	3585.10	4
5	2799.86	2862.08	2924.81	2988.12	3052.00	3116.51	3181.60	3247.37	3313.78	3380.83	3448.61	3517.08	3586.27	5
6	2800.89	2863.12	2925.86	2989.18	3053.07	3117.59	3182.69	3248.47	3314.89	3381.95	3449.75	3518.23	3587.43	6
7	2801.92	2864.16	2926.92	2990.24	3054.14	3118.67	3183.79	3249.57	3316.01	3383.08	3450.88	3519.38	3588.59	7
8	2802.96	2865.20	2927.97	2991.31	3055.21	3119.75	3184.88	3250.68	3317.12	3384.20	3452.02	3520.52	3589.75	8
9	2803.99	2866.25	2929.02	2992.37	3056.29	3120.83	3185.97	3251.78	3318.24	3385.33	3453.16	3521.67	3590.92	9
10	2805.02	2867.29	2930.07	2993.43	3057.36	3121.91	3187.06	3252.88	3319.35	3386.45	3454.29	3522.82	3592.08	10
11	2806.06	2868.33	2931.13	2994.49	3058.43	3122.99	3188.16	3253.98	3320.46	3387.58	3455.43	3523.97	3593.24	11
12	2807.09	2869.38	2932.18	2995.55	3059.50	3124.07	3189.25	3255.08	3321.58	3388.70	3456.57	3525.12	3594.41	12
13	2808.12	2870.42	2933.23	2996.62	3060.57	3125.15	3190.34	3256.19	3322.69	3389.83	3457.70	3526.26	3595.57	13
14	2809.16	2871.46	2934.28	2997.68	3061.64	3126.23	3191.43	3257.29	3323.80	3390.95	3458.84	3527.41	3596.73	14
15	2810.19	2872.51	2935.33	2998.74	3062.72	3127.32	3192.52	3258.39	3324.92	3392.08	3459.97	3528.56	3597.90	15
16	2811.22	2873.55	2936.39	2999.80	3063.79	3128.40	3193.62	3259.49	3326.03	3393.20	3461.11	3529.71	3599.06	16
17	2812.26	2874.59	2937.44	3000.86	3064.86	3129.48	3194.71	3260.59	3327.15	3394.33	3462.25	3530.86	3600.22	17
18	2813.29	2875.63	2938.49	3001.93	3065.93	3130.56	3195.80	3261.70	3328.26	3395.45	3463.38	3532.00	3601.38	18
19	2814.32	2876.68	2939.54	3002.99	3067.00	3131.64	3196.89	3262.80	3329.36	3396.58	3464.52	3533.15	3602.55	19
20	2815.36	2877.72	2940.60	3004.05	3068.07	3132.72	3197.99	3263.90	3330.49	3397.70	3465.66	3534.30	3603.71	20
21	2816.39	2878.76	2941.65	3005.11	3069.15	3133.80	3199.08	3265.00	3331.60	3398.83	3466.79	3535.45	3604.87	21
22	2817.42	2879.81	2942.70	3006.17	3070.22	3134.88	3200.17	3266.10	3332.71	3399.95	3467.93	3536.60	3606.04	22
23	2818.46	2880.85	2943.75	3007.24	3071.29	3135.96	3201.26	3267.21	3333.83	3401.08	3469.07	3537.74	3607.20	23
24	2819.49	2881.89	2944.81	3008.30	3072.36	3137.04	3202.36	3268.31	3334.94	3402.20	3470.20	3538.89	3608.36	24
25	2820.52	2882.94	2945.86	3009.36	3073.43	3138.13	3203.45	3269.41	3336.05	3403.33	3471.34	3540.04	3609.53	25
26	2821.56	2883.98	2946.91	3010.42	3074.50	3139.21	3204.54	3270.51	3337.17	3404.45	3472.47	3541.19	3610.69	26
27	2822.59	2885.02	2947.96	3011.48	3075.58	3140.29	3205.63	3271.61	3338.28	3405.58	3473.61	3542.34	3611.85	27
28	2823.62	2886.06	2949.01	3012.55	3076.65	3141.37	3206.73	3272.72	3339.40	3406.70	3474.75	3543.48	3613.01	28
29	2824.66	2887.11	2950.07	3013.61	3077.72	3142.45	3207.82	3273.82	3340.51	3407.83	3475.88	3544.63	3614.18	29

RAILROAD CURVE TABLES.

′	52°	53°	54°	55°	56°	57°	58°	59°	60°	61°	62°	63°	64°	′
30	2825.69	2888.15	2951.12	3014.67	3078.79	3143.53	3208.91	3274.92	3341.62	3408.95	3477.02	3545.78	3615.34	30
31	2826.73	2889.20	2952.18	3015.74	3079.87	3144.62	3210.01	3276.03	3342.74	3410.08	3478.16	3546.94	3616.51	31
32	2827.77	2890.24	2953.23	3016.80	3080.94	3145.70	3211.11	3277.14	3343.86	3411.22	3479.31	3548.09	3617.68	32
33	2828.81	2891.29	2954.29	3017.87	3082.02	3146.79	3212.20	3278.25	3344.98	3412.35	3480.45	3549.25	3618.85	33
34	2829.85	2892.34	2955.35	3018.93	3083.10	3147.88	3213.30	3279.36	3346.10	3413.48	3481.60	3550.40	3620.02	34
35	2830.89	2893.39	2956.40	3020.00	3084.18	3148.97	3214.40	3280.47	3347.22	3414.61	3482.74	3551.56	3621.19	35
36	2831.92	2894.43	2957.46	3021.06	3085.25	3150.05	3215.50	3281.58	3348.34	3415.75	3483.88	3552.72	3622.35	36
37	2832.96	2895.48	2958.51	3022.13	3086.33	3151.14	3216.60	3282.69	3349.46	3416.88	3485.03	3553.87	3623.52	37
38	2834.00	2896.53	2959.57	3023.20	3087.41	3152.23	3217.70	3283.80	3350.58	3418.01	3486.17	3555.03	3624.69	38
39	2835.04	2897.57	2960.63	3024.26	3088.48	3153.31	3218.80	3284.91	3351.69	3419.14	3487.32	3556.18	3625.86	39
40	2836.08	2898.62	2961.68	3025.33	3089.56	3154.40	3219.89	3286.02	3352.81	3420.28	3488.46	3557.34	3627.03	40
41	2837.12	2899.67	2962.74	3026.39	3090.64	3155.49	3220.99	3287.13	3353.93	3421.41	3489.60	3558.49	3628.20	41
42	2838.16	2900.71	2963.80	3027.46	3091.71	3156.57	3222.09	3288.24	3355.05	3422.54	3490.75	3559.65	3629.37	42
43	2839.20	2901.76	2964.85	3028.52	3092.79	3157.66	3223.19	3289.35	3356.17	3423.68	3491.89	3560.80	3630.54	43
44	2840.24	2902.81	2965.91	3029.59	3093.87	3158.75	3224.29	3290.46	3357.29	3424.81	3493.04	3561.96	3631.71	44
45	2841.28	2903.86	2966.96	3030.66	3094.95	3159.84	3225.38	3291.57	3358.41	3425.94	3494.18	3563.12	3632.88	45
46	2842.31	2904.90	2968.02	3031.72	3096.02	3160.92	3226.48	3292.68	3359.53	3427.07	3495.32	3564.27	3634.04	46
47	2843.35	2905.95	2969.08	3032.79	3097.10	3162.01	3227.58	3293.78	3360.65	3428.21	3496.47	3565.43	3635.21	47
48	2844.39	2907.00	2970.13	3033.85	3098.18	3163.10	3228.68	3294.89	3361.77	3429.34	3497.61	3566.58	3636.38	48
49	2845.43	2908.04	2971.19	3034.92	3099.25	3164.18	3229.78	3296.00	3362.89	3430.47	3498.77	3567.74	3637.55	49
50	2846.47	2909.09	2972.25	3035.98	3100.33	3165.27	3230.88	3297.11	3364.01	3431.60	3499.90	3568.89	3638.72	50
51	2847.51	2910.14	2973.30	3037.05	3101.41	3166.36	3231.97	3298.22	3365.13	3432.74	3501.04	3570.05	3639.89	51
52	2848.55	2911.18	2974.36	3038.11	3102.48	3167.44	3233.07	3299.33	3366.25	3433.87	3502.19	3571.21	3641.06	52
53	2849.59	2912.23	2975.41	3039.18	3103.56	3168.53	3234.17	3300.44	3367.37	3435.00	3503.33	3572.36	3642.23	53
54	2850.63	2913.28	2976.47	3040.25	3104.64	3169.62	3235.27	3301.55	3368.48	3436.13	3504.48	3573.52	3643.40	54
55	2851.67	2914.32	2977.53	3041.31	3105.72	3170.71	3236.37	3302.66	3369.60	3437.27	3505.62	3574.67	3644.57	55
56	2852.70	2915.36	2978.58	3042.38	3106.79	3171.79	3237.47	3303.77	3370.72	3438.40	3506.76	3575.83	3645.73	56
57	2853.74	2916.41	2979.64	3043.44	3107.87	3172.88	3238.56	3304.88	3371.84	3439.53	3507.91	3576.99	3646.90	57
58	2854.78	2917.46	2980.70	3044.51	3108.95	3173.97	3239.66	3305.99	3372.96	3440.67	3509.05	3578.14	3648.07	58
59	2855.82	2918.50	2981.75	3045.57	3110.02	3175.05	3240.76	3307.10	3374.08	3441.80	3510.20	3579.30	3649.24	59

RAILROAD CURVE TABLES.

′	65°	66°	67°	68°	69°	70°	71°	72°	73°	74°	75°	76°	77°	′
0	3650.41	3721.06	3792.57	3864.88	3938.11	4012.15	4087.15	4163.07	4239.97	4317.84	4396.74	4476.73	4557.81	0
1	3651.59	3722.25	3793.77	3866.10	3939,34	4013.40	4088.41	4164.35	4241.26	4319.15	4398.07	4478.08	4559.18	1
2	3652.76	3723.44	3794.97	3867.31	3940.57	4014.64	4089.67	4165.63	4242.56	4320.46	4399.40	4479.42	4560.54	2
3	3653.94	3724 62	3796.17	3868.53	3941.80	4015.89	4090.93	4166.90	4243.85	4321.77	4400.73	4480.77	4561.91	3
4	3655.11	3725.81	3797.38	3869.75	3943.03	4017.14	4092.19	4168.18	4245.14	4323.08	4402.06	4482.12	4563.27	4
5	3656.29	3727.00	3798.58	3870.97	3944.26	4018.39	4093.45	4169.46	4246.44	4324.39	4403.39	4483.46	4564.64	5
6	3657.46	3728.19	3799.78	3872.18	3945.49	4019.63	4094.71	4170.74	4247.73	4325.70	4404.71	4484.81	4566.01	6
7	3658.64	3729.38	3800.98	3873.40	3946.72	4020.88	4095.97	4172.02	4249.02	4327.01	4406.04	4486.16	4567.37	7
8	3659.81	3730.56	3802.18	3874.62	3947.95	4022.13	4097.24	4173.29	4250.31	4328.32	4407.37	4487.51	4568.74	8
9	3660.99	3731.75	3803.38	3875.83	3949.18	4023.37	4098.50	4174.57	4251.61	4329.63	4408.70	4488.85	4570.10	9
10	3662.16	3732.94	3804.58	3877.05	3950.41	4024.62	4099.76	4175.85	4252.90	4330.94	4410.03	4490.20	4571.47	10
11	3663.33	3734.13	3805.78	3878.27	3951.64	4025.87	4101.02	4177.13	4254.19	4332.25	4411.36	4491.55	4572.83	11
12	3664.51	3735.32	3806.99	3879.48	3952.87	4027.11	4102.28	4178.41	4255.49	4333.56	4412.69	4492.89	4574.20	12
13	3665.68	3736.50	3808.19	3880.70	3954.10	4028.36	4103.54	4179.68	4256.78	4334.87	4414.02	4494.24	4575.56	13
14	3666.86	3737.69	3809.39	3881.92	3955.33	4029.61	4104.80	4180.96	4258.07	4336.18	4415.35	4495.59	4576.93	14
15	3668.03	3738.88	3810.59	3883.14	3956.56	4030.86	4106.06	4182.24	4259.36	4337.49	4416.68	4496.93	4578.30	15
16	3669.21	3740.07	3811.79	3884.35	3957.79	4032.10	4107.32	4183.52	4260.66	4338.80	4418.01	4498.28	4579.66	16
17	3670.38	3741.26	3812.99	3885.57	3959.02	4033.35	4108.58	4184.80	4261.95	4340.11	4419.34	4499.63	4581.03	17
18	3671.56	3742.44	3814.19	3886.79	3960.25	4034.60	4109.84	4186.07	4263.24	4341.42	4420.67	4500.98	4582.39	18
19	3672.73	3743.63	3815.39	3888.00	3961.48	4035.84	4111.10	4187.35	4264.54	4342.73	4422.00	4502.32	4583.76	19
20	3673.90	3744.82	3816.60	3889.21	3962.71	4037.09	4112.36	4188.63	4265.83	4344.05	4423.33	4503.67	4585.12	20
21	3675.08	3746.01	3817.80	3890.43	3963.94	4038.34	4113.62	4189.91	4267.12	4345.36	4424.65	4505.01	4586.49	21
22	3676.25	3747.20	3819.00	3891.64	3965.17	4039.58	4114.89	4191.19	4268.42	4346.67	4425.98	4506.35	4587.86	22
23	3677.43	3748.38	3820.20	3892.86	3966.40	4040.83	4116.15	4192.46	4269.71	4347.98	4427.31	4507.70	4589.22	23
24	3678.60	3749.57	3821.40	3894.08	3967.63	4042.08	4117.41	4193.74	4271.00	4349.29	4428.64	4509.05	4590.59	24
25	3679.78	3750.76	3822.60	3895.29	3968.86	4043.33	4118.67	4195.02	4272.29	4350.60	4429.97	4510.39	4591.95	25
26	3680.95	3751.95	3823.80	3896.51	3970.09	4044.57	4119.93	4196.30	4273.59	4351.91	4431.30	4511.74	4593.32	26
27	3682.13	3753.14	3825.01	3897.74	3971.32	4045.82	4121.19	4197.57	4274.88	4353.22	4432.63	4513.09	4594.69	27
28	3683.30	3754.32	3826.21	3898.95	3972.55	4047.07	4122.45	4198.85	4276.17	4354.53	4433.96	4514.44	4596.05	28
29	3684.48	3755.51	3827.41	3900.16	3973.78	4048.81	4123.71	4200.13	4277.47	4355.84	4435.29	4515.78	4597.42	29

RAILROAD CURVE TABLES.

′	65°	66°	67°	68°	69°	70°	71°	72°	73°	74°	75°	76°	77°	′
30	3685.65	3756.70	3828.61	3901.38	3975.01	4049.56	4124.97	4201.41	4278.76	4357.15	4436.62	4517.13	4598.78	30
31	3686.83	3757.90	3829.82	3902.60	3976.25	4050.81	4126.24	4202.70	4280.06	4358.47	4437.96	4518.49	4600.15	31
32	3688.01	3759.09	3831.03	3903.83	3977.49	4052.07	4127.51	4203.98	4281.36	4359.79	4439.29	4519.84	4601.53	32
33	3689.19	3760.29	3832.24	3905.05	3978.72	4053.32	4128.78	4205.27	4282.67	4361.11	4440.63	4521.20	4602.91	33
34	3690.37	3761.48	3833.45	3906.28	3979.96	4054.57	4130.05	4206.55	4283.97	4362.43	4441.97	4522.55	4604.28	34
35	3691.55	3762.68	3834.66	3907.50	3981.20	4055.83	4131.32	4207.84	4285.27	4363.75	4443.30	4523.91	4605.66	35
36	3692.73	3763.87	3835.86	3908.73	3982.44	4057.08	4132.59	4209.12	4286.58	4365.07	4444.64	4525.27	4607.03	36
37	3693.91	3765.07	3837.07	3909.95	3983.68	4058.33	4133.86	4210.41	4287.88	4366.39	4445.98	4526.62	4608.41	37
38	3695.09	3766.27	3838.28	3911.17	3984.91	4059.58	4135.13	4211.69	4289.18	4367.71	4447.32	4527.98	4609.78	38
39	3696.27	3767.46	3839.49	3912.40	3986.15	4060.84	4136.40	4212.98	4290.48	4369.03	4448.65	4529.33	4611.16	39
40	3697.45	3768.66	3840.70	3913.62	3987.39	4062.09	4137.67	4214.26	4291.79	4370.35	4449.99	4530.69	4612.53	40
41	3698.63	3769.85	3841.91	3914.85	3988.63	4063.34	4138.94	4215.55	4293.09	4371.67	4451.33	4532.05	4613.91	41
42	3699.81	3771.05	3843.12	3916.07	3989.87	4064.60	4140.21	4216.83	4294.39	4372.99	4452.66	4533.40	4615.28	42
43	3700.99	3772.24	3844.33	3917.30	3991.10	4065.85	4141.48	4218.12	4295.69	4374.31	4454.00	4534.76	4616.66	43
44	3702.17	3773.44	3845.54	3918.52	3992.34	4067.10	4142.75	4219.40	4297.00	4375.63	4455.34	4536.11	4618.03	44
45	3703.35	3774.64	3846.75	3919.74	3993.58	4068.36	4144.02	4220.69	4298.30	4376.94	4456.67	4537.47	4619.41	45
46	3704.53	3775.83	3847.95	3920.97	3994.82	4069.61	4145.29	4221.98	4299.60	4378.26	4458.01	4538.83	4620.78	46
47	3705.72	3777.03	3849.16	3922.19	3996.06	4070.86	4146.56	4223.26	4300.91	4379.58	4459.35	4540.18	4622.16	47
48	3706.90	3778.22	3850.37	3923.42	3997.29	4072.11	4147.83	4224.55	4302.21	4380.90	4460.69	4541.54	4623.53	48
49	3708.08	3779.42	3851.58	3924.64	3998.52	4073.37	4149.10	4225.83	4303.51	4382.22	4462.02	4542.89	4624.91	49
50	3709.26	3780.61	3852.79	3925.87	3999.77	4074.62	4150.37	4227.12	4304.81	4383.54	4463.36	4544.25	4626.29	50
51	3710.44	3781.81	3854.00	3927.09	4001.01	4075.87	4151.64	4228.40	4306.12	4384.86	4464.70	4545.61	4627.66	51
52	3711.62	3783.01	3855.21	3928.31	4002.25	4077.13	4152.91	4229.69	4307.42	4386.18	4466.03	4546.96	4629.04	52
53	3712.80	3784.20	3856.42	3929.54	4003.48	4078.38	4154.18	4230.97	4308.72	4387.50	4467.37	4548.32	4630.41	53
54	3713.98	3785.40	3857.63	3930.76	4004.72	4079.63	4155.45	4232.26	4310.02	4388.82	4468.71	4549.67	4631.79	54
55	3715.16	3786.59	3858.84	3931.99	4005.96	4080.89	4156.72	4233.54	4311.33	4390.14	4470.04	4551.03	4633.16	55
56	3716.34	3787.79	3860.04	3933.21	4007.20	4082.14	4157.99	4234.83	4312.63	4391.46	4471.38	4552.39	4634.54	56
57	3717.52	3788.98	3861.25	3934.44	4008.44	4083.39	4159.26	4236.11	4313.93	4392.78	4472.72	4553.74	4635.91	57
58	3718.70	3790.18	3862.46	3935.66	4009.67	4084.64	4160.53	4237.40	4315.23	4394.10	4474.06	4555.10	4637.29	58
59	3719.88	3791.38	3863.67	3936.88	4010.91	4085.90	4161.80	4238.68	4316.54	4395.42	4475.39	4556.45	4638.66	59

RAILROAD CURVE TABLES.

′	78°	79°	80°	81°	82°	83°	84°	85°	86°	87°	88°	89°	′
0	4640.04	4723.41	4808.04	4893.88	4980.97	5069.44	5159.29	5250.57	5343.28	5437.54	5533.35	5630.81	0
1	4641.43	4724.82	4809.47	4895.33	4982.44	5070.93	5160.80	5252.11	5344.84	5439.13	5534.97	5632.46	1
2	4642.81	4726.22	4810.89	4896.77	4983.91	5072.42	5162.32	5253.65	5346 41	5440.72	5536.59	5634.10	2
3	4644.20	4727.63	4812.32	4898.22	4985.38	5073.92	5163.83	5255.19	5347.97	5442.31	5538.20	5635.75	3
4	4645.58	4729.03	4813.74	4899.66	4986.85	5075.41	5165.35	5256.73	5349.54	5443.90	5539.82	5637.39	4
5	4646.97	4730.44	4815.17	4901.11	4988.32	5076.90	5166.86	5258.27	5351.10	5445.50	5541.44	5639.04	5
6	4648.35	4731.85	4816.59	4902.56	4989.78	5078.39	5168.38	5259.81	5352.67	5447.09	5543.06	5640.69	6
7	4649.74	4733.25	4818.02	4904.00	4991.25	5079.88	5169.89	5261.35	5354.23	5448.68	5544.68	5642.33	7
8	4651.12	4734.66	4819.44	4905.45	4992.72	5081.38	5171.41	5262.88	5355.79	5450.27	5546.29	5643.98	8
9	4652.50	4736.06	4820.87	4906.89	4994.19	5082.87	5172.92	5264.42	5357.36	5451.86	5547.91	5645.63	9
10	4653.89	4737.47	4822.29	4908.34	4995.66	5084.36	5174.44	5265.96	5358.92	5453.45	5549.53	5647.27	10
11	4655.27	4738.87	4823.72	4909.78	4997.13	5085 85	5175.95	5267.50	5360.49	5455.04	5551.14	5648.92	11
12	4656.66	4740.28	4825.14	4911.23	4998.60	5087.34	5177.47	5269.04	5362.05	5456.63	5552.76	5650.57	12
13	4658.04	4741.68	4826.57	4912.68	5000.07	5088.84	5178.98	5270.58	5363.62	5458.22	5554.38	5652.21	13
14	4659.43	4743.09	4827.99	4914.12	5001.54	5090.33	5180.50	5272.12	5365.18	5459.81	5556.00	5653.86	14
15	4660.81	4744.50	4829.42	4915.57	5003.01	5091.82	5182.01	5273.66	5366.74	5461.41	5557.62	5655.50	15
16	4662.20	4745.90	4830.84	4917.01	5004.47	5093 31	5183.53	5275.20	5368.31	5463.00	5559.24	5657.15	16
17	4663.58	4747.31	4832.27	4918.46	5005.94	5094.80	5185.04	5276.74	5369.87	5464.59	5560.85	5658.80	17
18	4664.97	4748.71	4833.69	4919.91	5007.41	5096.30	5186.56	5278.28	5371.44	5466.18	5562.47	5660.44	18
19	4666.35	4750.12	4835.12	4921.35	5008.88	5097.79	5188.07	5279.82	5373.00	5467.77	5564.09	5662.09	19
20	4667.73	4751.52	4836.54	4922.79	5010.35	5099.28	5189.58	5281.36	5374.57	5469.36	5565.70	5663.74	20
21	4669.12	4752.93	4837.97	4924.24	5011.82	5100.77	5191.10	5282.90	5376.13	5470.95	5567.32	5665.38	21
22	4670.50	4754.34	4839.39	4925.69	5013.29	5102.26	5192.61	5284.44	5377.69	5472.54	5568.94	5667.03	22
23	4671.89	4755.74	4840.82	4927.13	5014.76	5103.76	5194.13	5285.97	5379.26	5474.13	5570.56	5668.67	23
24	4673.27	4757.15	4842.24	4928.58	5016.23	5105.25	5195.64	5287.51	5380.82	5475.72	5572.18	5670.32	24
25	4674.66	4758.55	4843.67	4930.02	5017.69	5106.74	5197.16	5289.05	5382.39	5477.32	5573.79	5671.97	25
26	4676.04	4759.96	4845.09	4931.47	5019.16	5108.23	5198.67	5290.59	5383.95	5478.91	5575.41	5673.61	26
27	4677.43	4761.37	4846.52	4932.92	5020.63	5109.72	5200.19	5292.13	5385.51	5480.50	5577.03	5675.26	27
28	4678.81	4762.77	4847.94	4934.36	5022.10	5111.22	5201.70	5293.67	5387.08	5482.09	5578.65	5676.91	28
29	4680.20	4764.18	4849.37	4935.81	5023.57	5112.71	5203.22	5295.21	5388.64	5483.68	5580.27	5678.55	29

TABLE OF MINUTES WITH CORRESPONDING DECIMALS.				TABLE OF SECONDS WITH CORRESPONDING DECIMALS.			
M.	D.	M.	D.	S.	D.	S.	D.
′	°	′	°	″	°	″	°
1	0.0166	31	0.5167	1	0.0002778	31	0.0086111
2	0.0333	32	0.5333	2	0.0005556	32	0.0088888
3	0.0500	33	0.5500	3	0.0008333	33	0.0091666
4	0.0667	34	0.5667	4	0.0011111	34	0.0094444
5	0.0833	35	0.5833	5	0.0013888	35	0.0097222
6	0.1000	36	0.6000	6	0.0016666	36	0.0100000
7	0.1167	37	0.6167	7	0.0019444	37	0.0102777
8	0.1333	38	0.6333	8	0.0022222	38	0.0105555
9	0.1500	39	0.6500	9	0.0025000	39	0.0108333
10	0.1667	40	0.6667	10	0.0027777	40	0.0111111
11	0.1833	41	0.6833	11	0.0030555	41	0.0113888
12	0.2000	42	0.7000	12	0.0033333	42	0.0116666
13	0.2167	43	0.7167	13	0.0036111	43	0.0119444
14	0.2333	44	0.7333	14	0.0038888	44	0.0122222
15	0.2500	45	0.7500	15	0.0041666	45	0.0125000
16	0.2667	46	0.7667	16	0.0044444	46	0.0127777
17	0.2833	47	0.7833	17	0.0047722	47	0.0130555
18	0.3000	48	0.8000	18	0.0050000	48	0.0133333
19	0.3167	49	0.8167	19	0.0052777	49	0.0136111
20	0.3333	50	0.8333	20	0.0055555	50	0.0138888
21	0.3500	51	0.8500	21	0.0058333	51	0.0141666
22	0.3667	52	0.8667	22	0.0061111	52	0.0144444
23	0.3833	53	0.8833	23	0.0063888	53	0.0147222
24	0.4000	54	0.9000	24	0.0066666	54	0.0150000
25	0.4167	55	0.9167	25	0.0069444	55	0.0152777
26	0.4333	56	0.9333	26	0.0072222	56	0.0155555
27	0.4500	57	0.9500	27	0.0075000	57	0.0158333
28	0.4667	58	0.9667	28	0.0077777	58	0.0161111
29	0.4833	59	0.9833	29	0.0080555	59	0.0163888
30	0.5000	60	1.0000	30	0.0083333	60	0.0166666

RAILROAD CURVE TABLE.

The following Table shows the distance from the point of intersection of the tangent lines to the beginning of one degree curves, for each 30′, the angle of deflection (=angle at center) being known.

I.=The given angle of deflection.
II.=The sought for distance.
III.=Difference for intermediate angles.

RAILROAD CURVE TABLE.

I		II	III	I		II	III	I		II	III
0°	0′	25.00	25.0	30°	30′	1562.17	26.8	60°	30′	3341.62	33.4
1		50.02	25.0	31		1589.04	26.9	61		3375.20	33.6
1	30	75.01	25.0	31	30	1616.03	27.0	61	30	3408.95	33.8
2		99.99	25.0	32		1643.08	27.0	62		3442.93	34.0
2	30	125.03	25.0	32	30	1670.12	27.0	62	30	3477.02	34.1
3		150.07	25.0	33		1697.28	27.2	63		3511.34	34.3
3	30	175.05	25.0	33	30	1724.56	27.3	63	30	3545.78	34.4
4		200.09	25.0	34		1751.83	27.3	64		3580.45	34.7
4	30	225.13	25.0	34	30	1779.22	27.4	64	30	3615.34	34.9
5		250.17	25.0	35		1806.67	27.4	65		3650.41	35.1
5	30	275.21	25.0	35	30	1834.17	27.5	65	30	3685.65	35.2
6		300.30	25.0	36		1861.79	27.6	66		3721.06	35.4
6	30	325.35	25.0	36	30	1889.47	27.7	66	30	3756.70	35.6
7		350.44	25.1	37		1917.26	27.8	67		3792.57	35.9
7	30	375.54	25.1	37	30	1945.05	27.8	67	30	3828.61	36.0
8		400.70	25.1	38		1973.01	27.9	68		3864.88	36.3
8	30	425.79	25.1	38	30	2001.03	28.0	68	30	3901.38	36.5
9		450.95	25.1	39		2029.11	28.1	69		3938.11	36.7
9	30	476.10	25.1	39	30	2057.30	28.2	69	30	3975.01	36.9
10		501.32	25.2	40		2085.55	28.2	70		4012.15	37.1
10	30	526.53	25.2	40	30	2113.91	28.4	70	30	4049.56	37.4
11		551.74	25.2	41		2142.33	28.4	71		4087.15	37.6
11	30	576.95	25.2	41	30	2170.92	28.6	71	30	4124.97	37.8
12		602.22	25.3	42		2199.52	28.6	72		4163.07	38.1
12	30	627.55	25.3	42	30	2228.28	28.8	72	30	4201.41	38.3
13		652.87	25.3	43		2257.10	28.8	73		4239.97	38.6
13	30	678.20	25.3	43	30	2286.04	28.9	73	30	4278.76	38.8
14		703.53	25.3	44		2315.09	29.0	74		4317.84	38.9
14	30	728.97	25.4	44	30	2344.20	29.1	74	30	4357.15	39.3
15		754.35	25.4	45		2373.42	29.2	75		4396.74	39.6
15	30	779.79	25.4	45	30	2402.76	29.3	75	30	4436.62	39.9
16		805.29	25.5	46		2432.21	29.4	76		4476.73	40.1
16	30	830.79	25.5	46	30	2461.78	29.6	76	30	4517.13	40.4
17		856.35	25.5	47		2491.46	29.7	77		4557.81	40.7
17	30	881.90	25.5	47	30	2521.26	29.8	77	30	4598.78	41.0
18		907.52	25.6	48		2551.11	29.8	78		4640.04	41.3
18	30	933.18	25.6	48	30	2581.13	30.0	78	30	4681.58	41.5
19		958.86	25.7	49		2611.27	30.1	79		4723.41	41.8
19	30	984.58	25.7	49	30	2641.53	30.3	79	30	4765.58	42.2
20		1010.37	25.8	50		2671.90	30.4	80		4808.04	42.5
20	30	1036.15	25.8	50	30	2702.44	30.5	80	30	4850.79	42.7
21		1062.00	25.8	51		2733.04	30.6	81		4893.88	43.1
21	30	1089.90	25.9	51	30	2763.81	30.8	81	30	4937.25	43.3
22		1113.80	25.9	52		2794.69	30.9	82		4980.97	43.7
22	30	1139.75	25.9	52	30	2825.69	31.0	82	30	5025.04	44.1
23		1165.76	26.0	53		2856.86	31.2	83		5069.44	44.4
23	30	1191.84	26.1	53	30	2888.15	31.3	83	30	5114.20	44.8
24		1217.96	26.1	54		2919.55	31.4	84		5159.29	45.1
24	30	1244.10	26.1	54	30	2951.12	31 6	84	30	5204.73	45.4
25		1270.28	26.2	55		2982.81	31.7	85		5250.57	45.8
25	30	1296.58	26.3	55	30	3014.67	31.9	85	30	5296.75	46.2
26		1322.88	26.3	56		3046.64	32.0	86		5343.28	46.5
26	30	1349.24	26.4	56	30	3078.79	32.2	86	30	5390.21	46.9
27		1375.65	26.4	57		3111.10	32.3	87		5437.54	47.3
27	30	1402.10	26.4	57	30	3143.53	32.4	87	30	5485.27	47.7
28		1428.65	26.5	58		3176.14	32.6	88		5533.35	48.1
28	30	1455.25	26.6	58	30	3208.91	32.8	88	30	5581.88	48.5
29		1481.89	26.6	59		3241.86	32.9	89		5630.81	48.9
29	30	1508.59	26.7	59	30	3274.92	33.1	89	30	5680.20	49.4
30		1535.30	26.7	60		3308.21	33.3	90		5730.00	49.8

EXCAVATION AND EMBANKMENT TABLES, FOR EXPEDITIOUSLY DETERMINING THE CUBIC YARDS FROM THE MEAN AREA.

EXPLANATION OF TABLES.

The tables are calculated for a distance of 100 feet between transverse sections.

In the left hand column are given the areas in feet. To obtain the cubic yards for areas, without decimals, look in the second column under the head of 0, and opposite the given area, find the cubic yards.

EXAMPLE.—Required the number of cubic yards for an area of 190 feet. In the second column under the head of 0, and opposite 190 in the first column, find 703.70 cubic yards.

To obtain the cubic yards for a less distance than 100 feet, multiply the cubic yards found in the tables by the given distance, and point off the fractional parts of 100 feet.

If the area has decimal parts, pass the eye to the right, opposite the area of the whole number, and under the head of such decimal will be found the number of yards.

EXAMPLE.—Required the cubic yards for an area of 105.4 feet. In the sixth column, under the head of 40, and opposite 105 in the first column, are given 390.37 cubic yards.

If the yards for an area greater than 354.90, and not exceeding 3549. feet, are required, the decimal point of the area given in the tables, and that of the cubic yards, being removed one figure to the right, will give the re-

uired yards. If there are decimal parts, add the cubic ards found opposite 0. in the first column, under the ead of such decimal.

EXAMPLE.—Required the cubic yards for an area of 975 feet; remove the decimal point one figure to the eft, and find the yards for an area of 197.5 feet=731.48, hen remove the decimal point one figure to the right and ou have 7314.8 cubic yards. If there is a decimal, add he cubic yards found for such decimal.

Or, to obtain the cubic yards for an area exceeding 549 feet, take one-half of the area, and seek the corre- ponding yards in tables and multiply the same by 2.

EXCAVATION AND EMBANKMENT TABLES.

	0.00	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90
0	0.00	0.37	0.74	1.11	1.48	1.85	2.22	2.59	2.96	3.33
1	3.70	4.07	4.45	4.81	5.19	5.66	5.93	6.30	6.67	7.04
2	7.41	7.78	8.15	8.52	8.89	9.26	9.63	10.00	10.37	10.74
3	11.11	11.48	11.85	12.22	12.59	12.96	13.33	13.70	14.07	14.44
4	14.82	15.19	15.56	15.93	16.30	16.67	17.04	17.41	17.78	18.15
5	18.52	18.89	19.26	19.63	20.00	20.37	20.74	21.11	21.48	21.85
6	22.22	22.59	22.96	23.33	23.70	24.07	24.44	24.82	25.19	25.56
7	25.93	26.30	26.67	27.04	27.41	27.78	28.15	28.52	28.89	29.26
8	29.63	30.00	30.37	30.74	31.11	31.48	31.85	32.22	32.59	32.96
9	33.33	33.70	34.07	34.44	34.82	35.19	35.56	35.93	36.30	36.67
10	37.04	37.41	37.78	38.15	38.52	38.89	39.26	39.63	40.00	40.37
11	40.74	41.11	41.48	41.85	42.22	42.59	42.96	43.33	43.70	44.07
12	44.44	44.82	45.19	45.56	45.93	46.30	46.67	47.04	47.41	47.78
13	48.15	48.52	48.89	49.26	49.63	50.00	50.37	50.74	51.11	51.48
14	51.85	52.22	52.59	52.96	53.33	53.70	54.07	54.44	54.82	55.19
15	55.56	55.93	56.30	56.67	57.04	57.41	57.78	58.15	58.52	58.89
16	59.26	59.63	60.00	60.37	60.74	61.11	61.48	61.85	62.22	62.59
17	62.96	63.33	63.70	64.07	64.44	64.82	65.19	65.56	65.93	66.30
18	66.67	67.04	67.41	67.78	68.15	68.52	68.89	69.26	69.63	70.00
19	70.37	70.74	71.11	71.48	71.85	72.22	72.59	72.96	73.33	73.70
20	74.07	74.44	74.82	75.19	75.56	75.93	76.30	76.67	77.04	77.41
21	77.78	78.15	78.52	78.89	79.26	79.63	80.00	80.37	80.74	81.11
22	81.48	81.85	82.22	82.59	82.96	83.33	83.70	84.07	84.44	84.82
23	85.19	85.56	85.93	86.30	86.67	87.04	87.41	87.78	88.15	88.52
24	88.89	89.26	89.63	90.00	90.37	90.74	91.11	91.48	91.85	92.22
25	92.59	92.96	93.33	93.70	94.07	94.44	94.82	95.19	95.56	95.93
26	96.30	96.67	97.04	97.41	97.78	98.15	98.52	98.89	99.26	99.63
27	100.00	100.37	100.74	101.11	101.48	101.85	102.22	102.59	102.96	103.33
28	103.70	104.07	104.44	104.82	105.19	105.56	105.93	106.30	106.67	107.04
29	107.41	107.78	108.15	108.52	108.89	109.26	109.63	110.00	110.37	110.74
30	111.11	111.48	111.85	112.22	112.59	112.96	113.33	113.70	114.07	114.44
31	114.81	115.18	115.56	115.92	116.29	116.67	117.03	117.40	117.77	118.15
32	118.52	118.89	119.26	119.63	120.00	120.37	120.74	121.11	121.48	121.85
33	122.22	122.59	122.96	123.33	123.70	124.07	124.44	124.81	125.18	125.55
34	125.92	126.30	126.66	127.03	127.40	127.77	128.14	128.51	128.88	129.26
35	129.63	130.00	130.37	130.74	131.11	131.48	131.85	132.22	132.59	132.96
36	133.33	133.70	134.07	134.44	134.81	135.18	135.55	135.92	136.29	136.67
37	137.04	137.41	137.78	138.15	138.52	138.89	139.26	139.63	140.00	140.37
38	140.74	141.11	141.48	141.85	142.22	142.59	142.96	143.33	143.70	144.07
39	144.44	144.81	145.18	145.55	145.92	146.29	146.66	147.03	147.40	147.78
40	148.15	148.52	148.89	149.26	149.63	150.00	150.37	150.74	151.11	151.48
41	151.85	152.22	152.59	152.96	153.33	153.70	154.07	154.44	154.81	155.18
42	155.55	155.92	156.29	156.66	157.03	157.40	157.77	158.14	158.51	158.89
43	159.26	159.63	160.00	160.37	160.74	161.11	161.48	161.85	162.22	162.59
44	162.96	163.33	163.70	164.07	164.44	164.81	165.18	165.55	165.92	166.30

quired yards. If there are decimal parts, add the cubic yards found opposite 0. in the first column, under the head of such decimal.

EXAMPLE.—Required the cubic yards for an area of 1975 feet; remove the decimal point one figure to the left, and find the yards for an area of 197.5 feet=731.48, then remove the decimal point one figure to the right and you have 7314.8 cubic yards. If there is a decimal, add the cubic yards found for such decimal.

Or, to obtain the cubic yards for an area exceeding 3549 feet, take one-half of the area, and seek the corresponding yards in tables and multiply the same by 2.

EXCAVATION AND EMBANKMENT TABLES.

	0.00	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90
0	0.00	0.37	0.74	1.11	1.48	1.85	2.22	2.59	2.96	3.33
1	3.70	4.07	4.45	4.81	5.19	5.56	5.93	6.30	6.67	7.04
2	7.41	7.78	8.15	8.52	8.89	9.26	9.63	10.00	10.37	10.74
3	11.11	11.48	11.85	12.22	12.59	12.96	13.33	13.70	14.07	14.44
4	14.82	15.19	15.56	15.93	16.30	16.67	17.04	17.41	17.78	18.15
5	18.52	18.89	19.26	19.63	20.00	20.37	20.74	21.11	21.48	21.85
6	22.22	22.59	22.96	23.33	23.70	24.07	24.44	24.82	25.19	25.56
7	25.93	26.30	26.67	27.04	27.41	27.78	28.15	28.52	28.89	29.26
8	29.63	30.00	30.37	30.74	31.11	31.48	31.85	32.22	32.59	32.96
9	33.33	33.70	34.07	34.44	34.82	35.19	35.56	35.93	36.30	36.67
10	37.04	37.41	37.78	38.15	38.52	38.89	39.26	39.63	40.00	40.37
11	40.74	41.11	41.48	41.85	42.22	42.59	42.96	43.33	43.70	44.07
12	44.44	44.82	45.19	45.56	45.93	46.30	46.67	47.04	47.41	47.78
13	48.15	48.52	48.89	49.26	49.63	50.00	50.37	50.74	51.11	51.48
14	51.85	52.22	52.59	52.96	53.33	53.70	54.07	54.44	54.82	55.19
15	55.56	55.93	56.30	56.67	57.04	57.41	57.78	58.15	58.52	58.89
16	59.26	59.63	60.00	60.37	60.74	61.11	61.48	61.85	62.22	62.59
17	62.96	63.33	63.70	64.07	64.44	64.82	65.19	65.56	65.93	66.30
18	66.67	67.04	67.41	67.78	68.15	68.52	68.89	69.26	69.63	70.00
19	70.37	70.74	71.11	71.48	71.85	72.22	72.59	72.96	73.33	73.70
20	74.07	74.44	74.82	75.19	75.56	75.93	76.30	76.67	77.04	77.41
21	77.78	78.15	78.52	78.89	79.26	79.63	80.00	80.37	80.74	81.11
22	81.48	81.85	82.22	82.59	82.96	83.33	83.70	84.07	84.44	84.82
23	85.19	85.56	85.93	86.30	86.67	87.04	87.41	87.78	88.15	88.52
24	88.89	89.26	89.63	90.00	90.37	90.74	91.11	91.48	91.85	92.22
25	92.59	92.96	93.33	93.70	94.07	94.44	94.82	95.19	95.56	95.93
26	96.30	96.67	97.04	97.41	97.78	98.15	98.52	98.89	99.26	99.63
27	100.00	100.37	100.74	101.11	101.48	101.85	102.22	102.59	102.96	103.33
28	103.70	104.07	104.44	104.82	105.19	105.56	105.93	106.30	106.67	107.04
29	107.41	107.78	108.15	108.52	108.89	109.26	109.63	110.00	110.37	110.74
30	111.11	111.48	111.85	112.22	112.59	112.96	113.33	113.70	114.07	114.44
31	114.81	115.18	115.56	115.92	116.29	116.67	117.03	117.40	117.77	118.15
32	118.52	118.89	119.26	119.63	120.00	120.37	120.74	121.11	121.48	121.85
33	122.22	122.59	122.96	123.33	123.70	124.07	124.44	124.81	125.18	125.55
34	125.92	126.30	126.66	127.03	127.40	127.77	128.14	128.51	128.88	129.26
35	129.63	130.00	130.37	130.74	131.11	131.48	131.85	132.22	132.59	132.96
36	133.33	133.70	134.07	134.44	134.81	135.18	135.55	135.92	136.29	136.67
37	137.04	137.41	137.78	138.15	138.52	138.89	139.26	139.63	140.00	140.37
38	140.74	141.11	141.48	141.85	142.22	142.59	142.96	143.33	143.70	144.07
39	144.44	144.81	145.18	145.55	145.92	146.29	146.66	147.03	147.40	147.78
40	148.15	148.52	148.89	149.26	149.63	150.00	150.37	150.74	151.11	151.48
41	151.85	152.22	152.59	152.96	153.33	153.70	154.07	154.44	154.81	155.18
42	155.55	155.92	156.29	156.66	157.03	157.40	157.77	158.14	158.51	158.89
43	159.26	159.63	160.00	160.37	160.74	161.11	161.48	161.85	162.22	162.59
44	162.96	163.33	163.70	164.07	164.44	164.81	165.18	165.55	165.92	166.30

EXCAVATION AND EMBANKMENT TABLES.

	0.00	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90
15	166.67	167.04	167.41	167.78	168.15	168.52	168.89	169.26	169.63	170.00
16	170.37	170.74	171.11	171.48	171.85	172.22	172.59	172.96	173.33	173.70
17	174.07	174.44	174.81	175.18	175.55	175.92	176.29	176.66	177.03	177.41
18	177.78	178.15	178.52	178.89	179.26	179.63	180.00	180.37	180.74	181.11
19	181.48	181.85	182.22	182.59	182.96	183.33	183.70	184.07	184.44	184.81
50	185.18	185.55	185.92	186.29	186.66	187.03	187.40	187.77	188.14	188.52
51	188.89	189.26	189.63	190.00	190.37	190.74	191.11	191.48	191.85	192.22
52	192.59	192.96	193.33	193.70	194.07	194.44	194.81	195.18	195.55	195.93
53	196.30	196.67	197.04	197.41	197.78	198.15	198.52	198.89	199.26	199.63
54	200.00	200.37	200.74	201.11	201.48	201.85	202.22	202.59	202.96	203.33
55	203.70	204.07	204.44	204.81	205.18	205.55	205.92	206.29	206.66	207.03
56	207.41	207.78	208.15	208.52	208.89	209.26	209.63	210.00	210.37	210.74
57	211.11	211.48	211.85	212.22	212.59	212.96	213.33	213.70	214.07	214.44
58	214.81	215.18	215.55	215.92	216.29	216 66	217.03	217.40	217.77	218.15
59	218.52	218.89	219.26	219.63	220.00	220.37	220.74	221.11	221.48	221.85
60	222.22	222.59	222.96	223.33	223.70	224.07	224.44	224.81	225.18	225.55
61	225.92	226.29	226.66	227.03	227.40	227.77	228.14	228.51	228.88	229.26
62	229.63	230.00	230.37	230.74	231.11	231.48	231.85	232.22	232.59	232.96
63	233.33	233.70	234.07	234.44	234 81	235.18	235.55	235.92	236.29	236.67
64	237.04	237.41	237.78	238.15	238.52	238.89	239.26	239.63	240.00	240.37
5	240.74	241.11	241.48	241.85	242.22	242.59	242.96	243.33	243.70	244.07
6	244.44	244.81	245.18	245.55	245.92	246.30	246.67	247.04	247.41	247.78
7	248.15	248.52	248.89	249.26	249.63	250.00	250.37	250.74	251.11	251.48
8	251.85	252.22	252.59	252.96	253.33	253.70	254.07	254.44	254.81	255.18
9	255.56	255.93	256.30	256.67	257.04	257.41	257.78	258.15	258.52	258.89
0	259.26	259.63	260.00	260.37	260.74	261.11	261.48	261.85	262.22	262.59
1	262.96	263.33	263.70	264.07	264.44	264.81	265.18	265.55	265.92	266.30
2	266.67	267.04	267.41	267.78	268.15	268.52	268.89	269.26	269.63	270.00
3	270.37	270.74	271.11	271.48	271.85	272.22	272.59	272.96	273.33	273.70
4	274.07	274.44	274.81	275.18	275.55	275.92	276.29	276.66	277.04	277.41
5	277.78	278.15	278.52	278.89	279.26	279.63	280.00	280.37	280.74	281.11
	281.48	281.85	282.22	282.59	282.96	283.33	283.70	284.07	284.44	284.81
7	285.18	285.56	285.93	286.30	286.67	287.04	287.41	287.78	288.15	288.52
	288.89	289.26	289.63	290.00	290.37	290.74	291.11	291.48	291.85	292.22
	292.59	292.96	293.33	293.70	294.07	294.44	294.81	295.18	295.55	295.93
	296.30	296.67	297.04	297.41	297.78	298.15	298.52	298.89	299.26	299.63
	300.00	300.37	300.74	301.11	301.48	301.85	302.22	302.59	302.96	303.33
	303.70	304.07	304.44	304 81	305.18	305.55	305.92	306.29	306.66	307.03
	307.41	307.78	308.15	308.52	308.89	309.26	309.63	310.00	310.37	310.74
	311.11	311.48	311.85	312.22	312.59	312.96	313.33	313.70	314.07	314.44
	314.81	315.19	315.56	315.93	316.30	316.67	317.04	317.41	317.78	318.15
	318.52	318.89	319.26	319.63	320.00	320.37	320.74	321.11	321.48	321.85
	322.22	322.59	322.96	323.33	323.70	324.07	324.44	324.81	325.18	325.55
	325.92	326.30	326.67	327.04	327.41	327.78	328.15	328.52	328.89	329.26
	329.63	330.00	330.37	330.74	331.11	331.48	331.85	332.22	332.59	332.96

EXCAVATION AND EMBANKMENT TABLES.

	0.00	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90
90	333.33	333.70	334.07	334.44	334.81	335.18	335.55	335.92	336.29	336.67
91	337.04	337.41	337.78	338.15	338.52	338.89	339.25	339.62	339.99	340.37
92	340.74	341.11	341.48	341.85	342.22	342.59	342.96	343.33	343.70	344.07
93	344.44	344.81	345.18	345.56	345.93	346.30	346.67	347.03	347.40	347.78
94	348.15	348.52	348.89	349.26	349.63	350.00	350.37	350.74	351.11	351.48
95	351.85	352.22	352.59	352.96	353.33	353.70	354.07	354.44	354.81	355.18
96	355.55	355.93	356.30	356.67	357.04	357.41	357.78	358.15	358.52	358.89
97	359.26	359.63	360.00	360.37	360.74	361.11	361.48	361.85	362.22	362.59
98	362.96	363.33	363.70	364.07	364.44	364.81	365.18	365.55	365.93	366.30
99	366.67	367.04	367.41	367.78	368.15	368.52	368.89	369.26	369.63	370.00
100	370.37	370.74	371.11	371.48	371.85	372.22	372.59	372.96	373.33	373.70
101	374.07	374.44	374.81	375.18	375.55	375.92	376.29	376.67	377.04	377.41
102	377.78	378.15	378.52	378.89	379.26	379.63	380.00	380.37	380.74	381.11
103	381.48	381.85	382.22	382.59	382.96	383.33	383.70	384.07	384.44	384.81
104	385 18	385.55	385.92	386.29	386.67	387.04	387.41	387.78	388.15	388.52
105	388.89	389.26	389.63	390.00	390.37	390.74	391.11	391.48	391.85	392.22
106	392.59	392.96	393.33	393.70	394.07	394.44	394.81	395.18	395.55	395.92
107	396.30	396.67	397.04	397.41	397.78	398.15	398.52	398.89	399.26	399.63
108	400.00	400.37	400.74	401.11	401.48	401.85	402.22	402.59	402.96	403.33
109	403.70	404.07	404.44	404.81	405.18	405.55	405 92	406.29	406.67	407.04
110	407.41	407.78	408.15	408.52	408.89	409.26	409.63	410.00	410.37	410.74
111	411.11	411.48	411.85	412.22	412.59	412.96	413.33	413.70	414.07	414.44
112	414.81	415.18	415.55	415.92	416.29	416.67	417.04	417.41	417.78	418.15
113	418.52	418.89	419.26	419.63	420.00	420.37	420.74	421.11	421.48	421.85
114	422.22	422.59	422.96	423.33	423.70	424.07	424.44	424.81	425.18	425.56
115	425.93	426.30	426.67	427.04	427.41	427.78	428.15	428.52	428.89	429.26
116	429.63	430.00	430.37	430.74	431.11	431.48	431.85	432.22	432.59	432.96
117	433.33	433.70	434.07	434.44	434.81	435.18	435.55	435.92	436.29	436.67
118	437.04	437.41	437.78	438.15	438.52	438.89	439.26	439.63	440.00	440.37
119	440.74	441.11	441.48	441.85	442.22	442.59	442.96	443.33	443.70	444.07
120	444.44	444.81	445.18	445.55	445.92	446.29	446.67	447.04	447.41	447.78
121	448.15	448.52	448.89	449.26	449.63	450.00	450.37	450.74	451.11	451.48
122	451.85	452.22	452.59	452.96	453.33	453.70	454.07	454.44	454.81	455.18
123	455.55	455.92	456.29	456.67	457.04	457.41	457.78	458.15	458.52	458.89
124	459.26	459.63	460.00	460.37	460.74	461.11	461.48	461.85	462.22	462.59
125	462.96	463.33	463.70	464.07	464.44	464.81	465.18	465.55	465.93	466.30
126	466.67	467.04	467.41	467.78	468.15	468.52	468.89	469.26	469.63	470.00
127	470.37	470.74	471.11	471.48	471.85	472.22	472.59	472.96	473.33	473.70
128	474.07	474.44	474.81	475.18	475.56	475.93	476.30	476.67	477.04	477.41
129	477.78	478.15	478.52	478.89	479.26	479.63	480.00	480.37	480.74	481.11
130	481.48	481.85	482.22	482.59	482.96	483.33	483.70	484.07	484.44	484.81
131	485.18	485.55	485.92	486.29	486.67	487.04	487.41	487.78	488.15	488 52
132	488.89	489.26	489.63	490.00	490.37	490.74	491.11	491.48	491.85	492.22
133	492.59	492.96	493.33	493.70	494.07	494.44	494.81	495.19	495.56	495.93
134	496.30	496.67	497.04	497.41	497.78	498.15	498.52	498.89	499.26	499.63

EXCAVATION AND EMBANKMENT TABLES.

	0.00	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90
135	500.00	500.37	500.74	501.11	501.48	501.85	502.22	502.59	502.96	503.33
136	503.70	504.07	504.44	504.81	505.18	505.56	505.93	506.30	506.67	507.04
137	507.41	507.78	508.15	508.52	508.89	509.26	509.63	510.00	510.37	510.74
138	511.11	511.48	511.85	512.22	512.59	512.96	513.33	513.70	514.07	514.44
139	514.81	515.18	515.55	515.92	516.29	516.67	517.04	517.41	517.78	518.15
140	518.52	518.89	519.26	519.63	520.00	520.37	520.74	521.11	521.48	521.85
141	522.22	522.59	522.96	523.33	523.70	524.07	524.44	524.81	525.19	525.56
142	525.93	526.30	526.67	527.04	527.41	527.78	528.15	528.52	528.89	529.26
143	529.63	530.00	530.37	530.74	531.11	531.48	531.85	532.22	532.59	532.94
144	533.33	533.70	534.07	534.44	534.81	535.18	535.56	535.93	536.30	536.67
145	537.04	537.41	537.78	538.15	538.52	538.89	539.26	539.63	540.00	540.37
146	540.74	541.11	541.48	541.85	542.22	542.59	542.96	543.33	543.70	544.07
147	544.44	544.81	545.18	545.56	545.93	546.30	546.67	547.04	547.41	547.78
148	548.15	548.52	548.89	549.26	549.63	550.00	550.37	550.74	551.11	551.48
149	551.85	552.22	552.59	552.96	553.33	553.70	554.07	554.44	554.81	555.18
150	555.55	555.93	556.30	556 67	557.04	557.41	557.78	558.15	558.52	558.89
151	559.26	559.63	560.00	560.37	560.74	561.11	561.48	561.85	562 22	562.59
152	562.96	563.33	563.70	564.07	564.44	564.81	565.18	565 56	565.93	566.30
153	566.67	567.04	567.41	567.78	568.15	568.52	568.89	569.26	569.63	570.00
154	570.37	570.74	571.11	571.48	571.85	572.22	572.59	572.96	573.33	573.70
155	574.07	574.44	574.81	575.18	575.56	575.93	576.30	576.67	577.04	577.41
156	577.78	578.15	578.52	578.89	579.26	579.63	580.00	580.37	580.74	581.11
157	581.48	581.85	582.22	582.59	582.96	583.33	583.70	584.07	584.44	584.81
158	585.18	585.55	585.92	586.29	586.66	587.04	587.41	587.78	588.15	588.52
159	588.89	589.26	589.63	590.00	590.37	590.74	591.11	591.48	591.85	592.22
160	592.59	592.96	593.33	593.70	594.07	594.44	594.81	595.18	595.55	595.92
161	596.29	596.67	597.04	597.41	597.78	598.15	598.52	598.89	599.26	599.63
162	600.00	600.37	600.74	601.11	601.48	601.85	602.22	602.59	602.96	603.33
163	603.70	604.07	604.44	604.81	605.18	605.55	605.92	606.30	606.67	607.04
164	607.41	607.78	608.15	608.52	608.89	609.26	609.63	610.00	610.37	610.74
165	611.11	611.48	611.85	612.22	612.59	612.96	613.33	613.70	614.07	614.44
166	614.81	615.18	615.55	615.92	616.29	616.67	617.04	617.41	617.78	618.15
167	618.52	618.89	619.26	619.63	620.00	620.37	620.74	621.11	621.48	621.85
168	622.22	622.59	622.96	623.33	623.70	624.07	624.44	624.81	625.18	625.56
169	625.93	626.30	626.67	627.04	627.41	627.78	628.15	628.52	628.89	629.26
170	629.63	630.00	630.37	630.74	631.11	631.48	631.85	632.22	632.59	632.96
171	633.33	633.70	634 07	634.44	634.81	635.18	635.55	635.92	636.29	636.66
172	637.04	637.40	637.77	638.14	638.51	638.88	639.25	639.62	639.99	640.37
173	640.74	641.11	641.48	641.85	642.22	642.59	642.96	643.33	643.70	644.07
174	644.44	644.81	645.18	645.55	645.92	646.29	646.66	647.03	647.41	647.78
175	648.15	648.52	648.89	649.26	649.63	650.00	650.37	650.74	651.11	651.48
176	651.85	652.22	652.59	652.96	653.33	653.70	654.07	654.44	654.81	655.18
177	655.56	655.93	656.30	656.67	657.04	657.41	657.78	658.15	658.52	658.89
178	659.26	659.63	660.00	660.37	660.74	661.11	661.48	661.85	662.22	662.59
179	662.96	663.33	663.70	664.07	664.44	664.81	665.18	665.55	665.92	666.29

EXCAVATION AND EMBANKMENT TABLES.

	0.00	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90
180	666.67	667.04	667.41	667.78	668.15	668.52	668.89	669.26	669.63	670.00
181	670.37	670.74	671.11	671.48	671.85	672.22	672.59	672.96	673.33	673.70
182	674.07	674.44	674.81	675.18	675.55	675.93	676.30	676.67	677.04	677.41
183	677.78	678.15	678.52	678.89	679.26	679.63	680.00	680.37	680.74	681.11
184	681.48	681.85	682.22	682.59	682.96	683.33	684.70	684.07	684.44	684.81
185	685.18	685.56	685.93	686.30	686.67	687.04	687.41	687.78	688.15	688.52
186	688.89	689.26	689.63	690.00	690.37	690.74	691.11	691.48	691.85	692.22
187	692.59	692.96	693.33	693.70	694.07	694.44	694.81	695.18	695.55	695 92
188	696.30	696.67	697.04	697.41	697.78	698.15	698.52	698.89	699.26	699.63
189	700.00	700.37	700.74	701.11	701.48	701.85	702.22	702.59	702.96	703.33
190	703.70	704.07	704.44	704.81	705.18	705.55	705.92	706.29	706.66	707.03
191	707.40	707.77	708.14	708.51	708.89	709.26	709.63	710.00	710.37	710.74
192	711.11	711.48	711.85	712.22	712.59	712.96	713.33	713.70	714.07	714.44
193	714.81	715.18	715.55	715.92	716.29	716.67	717.04	717.41	717.78	718.15
194	718.52	718.89	719.26	719.63	720.00	720.37	720.74	721.11	721.48	721.85
195	722.22	722.59	722.96	723.33	723.70	724.07	724.44	724.81	725.18	725.55
196	725.92	726.29	726.66	727.03	727.40	727.77	728.14	728.51	728.88	729.25
197	729.63	730.00	730.37	730.74	731.11	731.48	731.85	732.22	732.59	732.96
198	733.33	733.70	734.07	734.44	734.81	735.18	735.55	735.93	736.30	736.67
199	737.04	737.41	737.78	738.15	738.52	738.89	739.26	739.63	740.00	740.37
200	740.74	741.11	741.48	741.85	742.22	742.59	742.96	743.33	743.70	744.07
201	744.44	744.81	745.18	745.55	745.93	746.30	746.67	747.04	747.41	747.78
202	748.15	748.52	748.89	749.26	749.63	750.00	750.37	750.74	751.11	751.48
203	751.85	752.22	752.59	752.96	753.33	753.70	754.07	754.44	754.81	755.18
204	755.55	755.93	756.30	756.67	757.04	757.41	757.78	758.15	758.52	758.89
205	759.26	759.63	760.00	760.37	760.74	761.11	761.48	761.85	762.22	762.59
206	762.96	763.33	763.70	764.07	764.44	764.81	765.18	765.55	765.93	766.30
207	766.66	767.04	767.41	767.78	768.15	768.52	768.89	769.26	769.63	770.00
208	770.37	770.74	771.11	771.48	771.85	772.22	772.59	772.96	773.33	773.70
209	774.07	774.44	774.81	775.18	775.55	775.93	776.30	776.66	777.04	777.41
210	777.78	778.15	778.52	778.89	779.26	779.63	780.00	780.37	780.74	781.11
211	781.48	781.85	782.22	782.59	782.96	783.33	783.70	784.07	784.44	784.81
212	785.18	785.55	785.93	786.30	786.66	787.04	787.41	787.78	788.15	788.52
213	788.89	789.26	789.63	790.00	790.37	790.74	791.11	791.48	791.85	792.22
214	792.59	792.96	793.33	793.70	794.07	794.44	794.81	795.18	795.55	795.93
215	796.30	796.66	797.04	797.41	797.78	798.15	798.52	798.89	799.26	799.63
216	800.00	800.37	800.74	801.11	801.48	801.85	802.22	802.59	802.96	803.33
217	803.70	804.07	804.44	804.81	805.18	805.55	805.93	806.30	806.66	807.04
218	807.41	807.78	808.15	808.52	808.89	809.26	809.63	810.00	810.37	810.74
219	811.11	811.48	811.85	812.22	812.59	812.96	813.33	813.70	814.07	814.44
220	814.81	815.18	815.55	815.93	816.30	816.66	817.04	817.41	817.78	818.15
221	818.52	818.89	819.26	819.63	820.00	820.37	820.74	821.11	821.48	821.85
222	822.22	822.59	822.96	823.33	823.70	824.07	824.44	824.81	825.18	825.55
223	825.93	826.30	826.66	827.04	827.41	827.78	828.15	828.52	828.89	829.26
224	829.63	830.00	830.37	830.74	831.11	831.48	831.85	832.22	832.59	832.96

EXCAVATION AND EMBANKMENT TABLES.

	0.00	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90
225	833.33	833.70	834.07	834.44	834.81	835.18	835.55	835.93	836.30	836.66
226	837.04	837.41	837.78	838.15	838.52	838.89	839.26	839.63	840.00	840.37
227	840.74	841.11	841.48	841.85	842.22	842.59	842.96	843.33	843.70	844.07
228	844.44	844.81	845.18	845.55	845.93	846.30	846.66	847.04	847.41	847.78
229	848.15	848.52	848.89	849.26	849.63	850.00	850.37	850.74	851.11	851.48
230	851.85	852.22	852.59	852.96	853.33	853.70	854.07	854.44	854.81	855.18
231	855.55	855.93	856.30	856.66	857.04	857.41	857.78	858.15	858.52	858.89
232	859.26	859.63	860.00	860.37	860.74	861.11	861.48	861.85	862.22	862.59
233	862.96	863.33	863.70	864.07	864.44	864.81	865.18	865.55	865.93	866.30
234	866.66	867.04	867.41	867.78	868.15	868.52	868.89	869.26	869.63	870.00
235	870.37	870.74	871.11	871.48	871.85	872.22	872.59	872.96	873.33	873.70
236	874.07	874.44	874.81	875.18	875.55	875.93	876.30	876.66	877.04	877.41
237	877.78	878.15	878.52	878.89	879.26	879.63	880.00	880.37	880.74	881.11
238	881.48	881.85	882.22	882.59	882.96	883.33	883.70	884.07	884.44	884.81
239	885.18	885.55	885.93	886.30	886.66	887.04	887.41	887.78	888.15	888.52
240	888.88	889.26	889.63	890.00	890.37	890.74	891.11	891.48	891.88	892.22
241	892.59	892.96	893.33	893.70	894.07	894.44	894.81	895.18	895.55	895.93
242	896.30	896.66	897.04	897.41	897.78	898.15	898.52	898.88	899.26	899.63
243	900.00	900.37	900.74	901.11	901.48	901.85	902.22	902.59	902.96	903.33
244	903.70	904.07	904.44	904.81	905.18	905.55	905.93	906.30	906.66	907.04
245	907.41	907.78	908.15	908.52	908.88	909.26	909.63	910.00	910.37	910.74
246	911.11	911.48	911.85	912.22	912.59	912.96	913.33	913.70	914.07	914.44
247	914.81	915.18	915.55	915.93	916.30	916.66	917.04	917.41	917.78	918.15
248	918.52	918.88	919.26	919.63	920.00	920.37	920.74	921.11	921.48	921.85
249	922.22	922.59	922.96	923.33	923.70	924.07	924.44	924.81	925.18	925.55
250	925.92	926.30	926.66	927.04	927.41	927.78	928.15	928.52	928.88	929.26
251	929.63	930.00	930.37	930.74	931.11	931.48	931.85	932.22	932.59	932.96
252	933.33	933.70	934.07	934.44	934.81	935.18	935.55	935.92	936.30	936.66
253	937.04	937.41	937.78	938.15	938.52	938.88	939.26	939.63	940.00	940.37
254	940.74	941.11	941.48	941.85	942.22	942.59	942.96	943.33	943.70	944.07
255	944.44	944.81	945.18	945.55	945.92	946.30	946.66	947.04	947.41	947.78
256	948.15	948.52	948.88	949.26	949.63	950.00	950.37	950.74	951.11	951.48
257	951 85	952.22	952.59	952.96	953.33	953.70	954.07	954.44	954.81	955.18
258	955.55	955.92	956.30	956.66	957.04	957.41	957.78	958.15	958.52	958.88
259	959.26	959.63	960.00	960.37	960.74	961.11	961.48	961.85	962.22	962.59
260	962.96	963.33	963.70	964.07	964.44	964.81	965.18	965.55	965.92	966.30
261	966.66	967.04	967.41	967.78	968.15	968.52	968.88	969.26	969.63	970.00
262	970.37	970.74	971.11	971.48	971 85	972.22	972.59	972.96	973.33	973.70
263	974.07	974.44	974.81	975.18	975.55	975.92	976.30	976.66	977.04	977.41
264	977.78	978.15	978.52	978.88	979.26	979.63	980.00	980.37	980.74	981.11
265	981.48	981.85	982.22	982.59	982.96	983.33	983.70	984.07	984.44	984.81
266	985.18	985.55	985.92	986.30	986.66	987.04	987.41	987.78	988.15	988.52
267	988.88	989.26	989.63	990.00	990.37	990.74	991.11	991.48	991.85	992.22
268	992.59	992.96	993.33	993.70	994.07	994.44	994.81	995.18	995.55	995.92
269	996.30	996.66	997.04	997.41	997.78	998.15	998.52	998.88	999.26	999.63

EXCAVATION AND EMBANKMENT TABLES.

	0.00	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90
270	1000.00	1000.37	1000.74	1001.11	1001.48	1001.85	1002.22	1002.59	1002.96	1003.33
271	1003.70	1004.07	1004.44	1004.81	1005.18	1005.55	1005.92	1006.30	1006.66	1007.04
272	1007.41	1007.78	1008.15	1008.52	1008.88	1009.26	1009.63	1010.00	1010.37	1010.74
273	1011.11	1011.48	1011.85	1012.22	1012.59	1012.96	1013.33	1013.70	1014.07	1014.44
274	1014.81	1015.18	1015.55	1015.92	1016.30	1016.66	1017.04	1017.41	1017.78	1018.15
275	1018.52	1018.88	1019.26	1019.63	1020.00	1020.37	1020.74	1021.11	1021.48	1021.85
276	1022.22	1022.59	1022.96	1023.33	1023.70	1024.07	1024 44	1024.81	1025.18	1025.55
277	1025.92	1026.30	1026.66	1027.04	1027.41	1027.78	1028.15	1028.52	1028.88	1029.26
278	1029.63	1030.00	1030.37	1030.74	1031.11	1031.48	1031.85	1032.22	1032.59	1032.96
279	1033.33	1033.70	1034.07	1034.44	1034.81	1035.18	1035.55	1035.92	1036.30	1036.66
280	1037.04	1037.41	1037.78	1038.15	1038.52	1038.88	1039.26	1039.63	1040.00	1040.37
281	1040.74	1041.11	1041.48	1041.85	1042.22	1042.59	1042.96	1043.33	1043.70	1044.07
282	1044.44	1044.81	1045.18	1045.55	1045.92	1046.30	1046.66	1047.04	1047.41	1047.78
283	1048.15	1048.52	1048.88	1049.26	1049.63	1050.00	1050.37	1050.74	1051.11	1051.48
284	1051.85	1052.22	1052.59	1052.96	1053.33	1053.70	1054.07	1054.44	1054.81	1055.18
285	1055.55	1055.92	1056.30	1056.66	1057.04	1057.41	1057.78	1058.15	1058.52	1058.88
286	1059.26	1059.63	1060.00	1060.37	1060.74	1061.11	1061.48	1061.85	1062.22	1062.59
287	1062.96	1063.33	1063.70	1064.07	1064.44	1064.81	1065.18	1065.55	1065.92	1066.30
288	1066.66	1067.04	1067.41	1067.78	1068.15	1068.52	1068.88	1069.26	1069.63	1070.00
289	1070.37	1070.74	1071.11	1071.48	1071.85	1072.22	1072.59	1072.96	1073.33	1073.70
290	1074.07	1074.44	1074.81	1075.18	1075.55	1075.92	1076.30	1076.66	1077.04	1077.41
291	1077.78	1078.15	1078.52	1078.88	1079.26	1079.63	1080.00	1080.37	1080.74	1081.11
292	1081.48	1081.85	1082.22	1082.59	1082.96	1083.33	1083.70	1084.07	1084.44	1084.81
293	1085.18	1085.55	1085.92	1086.30	1086.66	1087.04	1087.41	1087.78	1088.15	1088.52
294	1088.88	1089.26	1089.63	1090.00	1090.37	1090.74	1091.11	1091.48	1091.85	1092.22
295	1092.59	1092.96	1093.33	1093.70	1094.07	1094.44	1094.81	1095.18	1095.55	1095.92
296	1096.30	1096.66	1097.04	1097.41	1097.78	1098.15	1098.52	1098.88	1099.26	1099.63
297	1100.00	1100.37	1100.74	1101.11	1101.48	1101.85	1102.22	1102.59	1102.96	1103.33
298	1103.70	1104.07	1104.44	1104.81	1105.18	1105.55	1105.92	1106.30	1106.66	1107.04
299	1107.41	1107.78	1108.15	1108.52	1108.88	1109.26	1109.63	1110.00	1110.37	1110.74
300	1111.11	1111.48	1111.85	1112.22	1112.59	1112.96	1113.33	1113.70	1114.07	1114.44
301	1114.82	1115.19	1115.56	1115.93	1116.30	1116.67	1117.04	1117.41	1117.78	1118.15
302	1118.52	1118.89	1119.26	1119.63	1120.00	1120.37	1120.74	1121.11	1121.48	1121.85
303	1122.22	1122.59	1122.96	1123.33	1123.70	1124.07	1124.44	1124.82	1125.19	1125.56
304	1125.93	1126.30	1126.67	1127.04	1127.41	1127.78	1128.15	1128.52	1128.89	1129.26
305	1129.63	1130.00	1130.37	1130.74	1131.11	1131.48	1131.85	1132.22	1132.59	1132.96
306	1133.33	1133.70	1134.07	1134.44	1134.82	1135.19	1135.56	1135.93	1136.30	1137.67
307	1137.04	1137.41	1137.78	1138.15	1138.52	1138.89	1139.26	1139.63	1140.00	1140.37
308	1140.74	1141.11	1141.48	1141.85	1142.22	1142.59	1142.96	1143.33	1143.70	1144.07
309	1144.44	1144.82	1145.19	1145.56	1145.93	1146.30	1146.67	1147.04	1147.41	1147.78
310	1148.15	1148.52	1148.89	1149.26	1149.63	1150.00	1150.37	1150.74	1151.11	1151.48
311	1151.85	1152.22	1152.59	1152.96	1153.33	1153.70	1154.07	1154.44	1154.82	1155.19
312	1155.56	1155.93	1156.30	1156.67	1157.04	1157.41	1157.78	1158.15	1158.52	1158.89
313	1159.26	1159.63	1160.00	1160.37	1160.74	1161.11	1161.48	1161.85	1162.22	1162.59
314	1162.96	1163.33	1163.70	1164.07	1164.44	1164.82	1165.19	1165.56	1165.93	1166.30

EXCAVATION AND EMBANKMENT TABLES.

	0.00	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90
315	1166.67	1167.04	1167.41	1167.78	1168.15	1168.52	1168.89	1169.26	1169.63	1170.00
316	1170.37	1170.74	1171.11	1171.48	1171.85	1172.22	1172.59	1172.96	1173.33	1173.70
317	1174.07	1174.44	1174.82	1175.19	1175.56	1175.93	1176.30	1176.67	1177.04	1177.41
318	1177.78	1178.15	1178.52	1178.89	1179.26	1179.63	1180.00	1180.37	1180.74	1181.11
319	1181.48	1181.85	1182.22	1182.59	1182.96	1183 33	1183.70	1184.07	1184.44	1184.82
320	1185.19	1185.56	1185.93	1186.30	1186.67	1187.04	1187.41	1187.78	1188.15	1188.52
321	1188.89	1189.26	1189.63	1190.00	1190.37	1190.74	1191.11	1191.48	1191.85	1192.22
322	1192 59	1192.96	1193.33	1193.70	1194.07	1194.44	1194.82	1195.19	1195.56	1195.93
323	1196.30	1196.67	1197.04	1197.41	1197.78	1198.15	1198.52	1198.89	1199.26	1199.63
324	1200.00	1200.37	1200.74	1201.11	1201.48	1201.85	1202.22	1202.59	1202.96	1203.33
325	1203.70	1204.07	1204.44	1204.82	1205.19	1205.56	1205.93	1206.30	1206.67	1207.04
326	1207.41	1207.78	1208.15	1208.52	1208.89	1209.26	1209.63	1210.00	1210.37	1210.74
327	1211.11	1211.48	1211.85	1212.22	1212.59	1212.96	1213.33	1213.70	1214.07	1214.44
328	1214.82	1215.19	1215.56	1215.93	1216.30	1216.67	1217.04	1217.41	1217.78	1218.15
329	1218.52	1218.89	1219.26	1219.63	1220.00	1220.37	1220.74	1221.11	1221.48	1221.86
330	1222.22	1222.59	1222.96	1223.33	1223.70	1224.07	1224.44	1224.81	1225.18	1225.55
331	1225.93	1226.30	1226.67	1227.04	1227.41	1227.78	1228.15	1228.52	1228.89	1229.26
332	1229.63	1230.00	1230.37	1230.74	1231.11	1231.48	1231.85	1232.22	1232.59	1232.96
333	1233.33	1233.70	1234.07	1234.44	1243.82	1235.19	1235.56	1235.93	1236.30	1236.67
334	1237.04	1237.41	1237.78	1238.15	1238.52	1238.89	1239.26	1239.63	1240.00	1240.37
335	1240.74	1241.11	1241.48	1241.85	1242.22	1242.59	1242.96	1243.33	1243.70	1244.07
336	1244.44	1244.82	1245.19	1245.56	1245.93	1246.30	1246.67	1247.04	1247.41	1247.78
337	1248.15	1248.52	1248.89	1249.26	1249.63	1250.00	1250.37	1250.74	1251.11	1251.48
338	1251.85	1252.22	1252.59	1252.96	1253.33	1253.70	1254.07	1254.44	1254.82	1255.19
339	1255.56	1255.93	1256.30	1256.67	1257.04	1257.41	1257.73	1258.15	1258.52	1258.89
340	1259.26	1259.63	1260.00	1260.37	1260.74	1261.11	1261.48	1261.85	1262.22	1262.59
341	1262.96	1263.33	1263.70	1264.07	1264.44	1264.82	1265.19	1265.56	1265.93	1266.30
342	1266.67	1267.04	1267.41	1267.78	1268.15	1268.52	1268.89	1269.26	1269.63	1270.00
343	1270.37	1270.74	1271.11	1271.48	1271.85	1272.22	1272.59	1272.96	1273.33	1273.70
344	1274.07	1274.44	1274.82	1275.19	1275.56	1275.93	1276.30	1276.67	1277.04	1277.41
345	1277.78	1278.15	1278.52	1278.89	1279.26	1279.63	1280.00	1280.37	1280.74	1281.11
346	1281.48	1281.85	1282.22	1282.59	1282.96	1283.33	1283.70	1284.07	1284.44	1284.82
347	1285.19	1285.56	1285.93	1286.30	1286.67	1287.04	1287.41	1287.78	1288.15	1288.52
348	1288.89	1289.26	1289.63	1290.00	1290.37	1290.74	1291.11	1291.48	1291.85	1292.22
349	1292.59	1292.96	1293.33	1293.70	1294.07	1294.44	1294.82	1295.19	1295.56	1295.93
350	1296.30	1296.67	1297.04	1297.41	1297.78	1298.15	1298.52	1298.89	1299.26	1299.63
351	1300.00	1300.37	1300.74	1301.11	1301.48	1301.85	1302.22	1302.59	1302.96	1303.33
352	1303.70	1304.07	1304.44	1304.82	1305.19	1305.56	1305.93	1306.30	1306.67	1307.04
353	1307 41	1307.78	1308.15	1308.52	1308.89	1309.26	1309.63	1310.00	1310.37	1310.74
354	1311.11	1311.48	1311.85	1312.22	1312.59	1312.96	1313.33	1313.70	1314.07	1314.44
355	1314.82	1315.19	1315.56	1315.93	1316.30	1316.67	1317.04	1317.41	1317.78	1318.15
356	1318.52	1318.89	1319.26	1319.63	1320 00	1320.37	1320.74	1321.11	1321.48	1321.86
357	1322 22	1322.59	1322.96	1323.33	1323.70	1324.07	1324.44	1324.81	1325.18	1325.55
358	1325.93	1326.30	1326.67	1327.04	1327.41	1327.78	1328.15	1328.52	1328.89	1329.26
359	1329.63	1330.00	1330.37	1330.74	1331.11	1331.48	1331.85	1332.22	1332.59	1332.96

APPENDIX B.

The following definitions, while not exhaustive, may, perhaps, be found serviceable:

ABBREVIATIONS USED BY ENGINEERS.

B. C. or *P. C.*—Beginning of Curve, or Point of Curve.
P. T.—Point of Tangent, or end of Curve.
P. C. C.—Point of Compound Curve, or end of one curve and beginning of another, curving in the same direction.
P. R. C.—Point of Reverse Curve, or point where the direction of the curve is changed from right to left, or vice versa.
P. I.—Point of Intersection of Tangents.
E. C.—Point of end of Curve.

NOTE.—It will be noticed that one writer who is quoted in this volume refers to the beginning of curve as B. C., while another who is also quoted refers to it as P. C.

Cross-Ties.—Terms Defined: There are wide differences in the terms used to describe various sorts of ties and also to indicate their condition. The following definitions are considered to comprise those in most general use, and, on the whole, are perhaps, the best.

Doty Tie.—A tie containing "dote" or dry rot.

Heart Tie.—A tie which shows sap wood only on the corners, the sap wood measuring more than 1 inch on lines drawn diagonally across the end of tie.

—One made from a cypress tree affected
disease, known locally as peck. This does
/ affect the usefulness of the tie.

One made from a tree from which not more
an be made from a section. Such ties gen-
p wood on two sides.

Tie.—One made from a tree, the size of
not more than four ties to be made from

One hewn or sawed on top and bottom only.

One showing more than a prescribed amount
n the cross section.

s.—Made with an ax as a guide for hewing.

One made from a tree whose size prevented
ties being made from a section.

t Tie.—One showing no sap wood in

.—One made from a tree from which the
ntine was extracted before it was felled.

-A device placed between the rail and the
the wear of the latter.

-One having a bend or crook in its length.

e.—A certain defect in the timber caused
of the wind upon a growing tree, resulting
n or separation of the fibers.

ettized.—A method of preserving timber,
oride. Invented by Burnett. Used largely

soted.—Probably the most effective pre-
the most expensive for initial cost.

ized.—Invented by Kyan and largely used

in Europe. Introduced in America in 1838, but not much used here. It employs bi-chloride of mercury or corrosive sublimate.

Ties.—Willhouse Treatment.—Consists of injections of zinc chloride followed by solutions of glue and tannin. Makes an artificial leather and plugs up the ducts. Results are said to be quite satisfactory.

TRACK DEFINITIONS.

Alignment.—Location with reference to curves and tangents.

Curve.—A series of changes in direction according to a fixed or regular method.

Curve Easement.—A curve of regularly varying radii, which connects a tangent to a simple curve, or which connects two simple curves.

Curve, Simple.—A series of uniform changes in direction laid out according to a fixed method.

Curve, Vertical.—A curve which is used to connect intersecting grade lines.

Elevation (as applied to curves).—The amount which the outer rail is raised above the inner rail.

Gauge (of track)—The shortest distance between the inside of the heads of the two rails forming the track, measured between parallel surfaces, perpendicular to the plane through tops of the two rails, and projecting 1⅜ inches below the plane.

Gauge, Standard.—The gauge or width of 4 feet 8½ inches.

Gauge (Track Tool—Standard Specifications).—The gauge recommended is a wooden bar with parallel metal measuring surfaces fastened rigidly to it, perpendicular

to plane on top of rails and extending to a depth of 1⅜ inches below the same.

Level.—The condition of the track as to the equal elevation of the rails transversely.

Line.—The condition of the track in regard to uniformity in direction over short distances on tangents, or uniformity in variation in direction over short distances on curves.

Surface.—The condition of the track as to vertical evenness or smoothness over short distances.

Tangent.—Straight track.

Track.—Ties, rails and fastenings, with all parts in their proper relative places.

Trestle, Wooden.—Terms Employed.

Batter.—Used to refer to the deviation from a perpendicular in upright members of a bent.

Bent.—The members, or group of members which form a single vertical support of a trestle. Called a "Pile Bent" when the principal members are piles, and a "Frame Bent" when of framed timbers.

Bulkhead.—Used to describe timber when it is placed on edge against the side of an end bent in order to retain an embankment.

Cap.—The horizontal member placed on the tops of piles or posts and which serves to connect them in the form of a bent.

Dowel.—The name applied to a short pin of wood or iron which is used to connect timbers.

Drift Bolt.—A long piece of iron (round or square) and with or without either a head or a point which is driven as a spike.

Frame Trestle.—So designated when its vertical members or supports are framed timbers.

Guard Rails.—Longitudinal members of either iron or wood fastened on top of the ties alongside the track.

Intermediate Sill.—A horizontal member in the plane of the bent between the cap and lower sill into which the posts are framed.

Longitudinal Struts or Girts.—Stiff members which are placed horizontally or almost so from bent to bent.

Longitudinal X Braces.—Members which extend diagonally from bent to bent in vertical planes.

Packing Spools or Separators.—Small castings used in connection with packing bolts to hold the stringers in their relative position.

Pile Trestle.—One in which the vertical members or supports are piles.

Piles.—Timbers driven in the ground and intended generally to support a structure.

Posts.—The vertical and battered members of the bent of a framed trestle.

Sash Braces.—Members secured horizontally to the posts or piles of a bent.

Shim.—A block used to raise any portion of a structure (and is generally evidence of faulty construction).

Sill.—The lower horizontal member of a framed bent.

Stringers.—The longitudinal members extending from bent to bent and supporting the ties.

Subsills.—Timbers bedded in the ground to support framed bents.

Sway Braces.—Members bolted or spiked to the bent and extending diagonally across its face.

Ties.—Transverse timbers resting on the stringers and supporting the track.

APPENDIX C.

Description and illustrations showing the latest and most improved methods for protecting piling by the use of concrete.

CONCRETE.

Concrete is entering more and more into railway construction. Its adaptability for bridge construction has

Method of Placing Lock Joint Pipe.

been fully demonstrated; without it the rapid elevation of railway tracks which has been going on, particularly

in Chicago, during the past year or two would have been impossible of accomplishment, and many other great engineering feats would probably not have been achieved, certainly not as rapidly.

Concrete is now being tested as a substitute for wooden ties, and now it seems to have been the means of solving the question of preserving piles when submerged in water, especially salt water in which the marine wood borers have often attacked and rendered useless creosoted piles.

This application of concrete is what is known as the Lock Joint Pipe for pile protection. These concrete pipes are made in halves, divided longitudinally, each half having a keyway which forms a scarf joint when they are placed together and keyed. Thus the pipe may be placed around the pile and locked with a key which seals the joint so absolutely tight that the finest of sand cannot get through it. After the pipe has been placed around the pile and securely locked, the space between the pile and the inside of the pipe is filled up with sand. The pile being surrounded with sand is therefore left perfectly free to settle with any scour which might occur at the mud line or bottom, and so is fully protected under all conditions.

After the sand has been allowed to settle the tops of the pipes are sealed with a thin coating of cement mortar, thus preventing the sand from being washed out by the waves in a storm.

Engineers and Roadmasters having the maintenance of trestles on pile bents submerged in tidal salt water have always experienced trouble with the teredo which attacks a pile at all points from the high-water line to the mud

PACIFIC LOCK JOINT
Showing Pipe in Place.

Making Lock Joint Pipe for Great Northern Railway at Everett, Wash

Lock Joint Pipe on Batter Piles.

line or bottom, but to live it is necessary for them to have free access to sea water. It is a well known fact that the teredo never works below the mud line. The Lock Joint Pipe unlike most other styles of pipe protection can be placed around piles already in use, and when such piles have been attacked by the teredo it can be readily seen that filling the annular space between the pipe and the pile with sand and then sealing it at top with cement mortar not only kills those which have attacked the pile, but has the effect of raising the mud line, or bottom, above the high-water line, which effectually prevents further attack from the teredo. It is claimed for this method of pile protection that all teredos in a pile have been completely destroyed within from twenty-four to seventy-two hours.

Concrete Lock Joint Pipe seems to combine all the good and to eliminate all the bad features of the various methods of protection for piles. The fact that its employment does not necessitate the removal of caps; that the pile is left free to settle or move without danger of exposure at the mud line, through scouring, a most vital point of attack by teredos; that the joint is so absolutely tight; that only the portion of a pile which is exposed to attack need be protected; and the ease with which any portion may be quickly and inexpensively repaired when necessary are bound to win favor with railway men. Many railroads, particularly in the south, have protected their piling with these Lock Joint Pipes of concrete and the Great Northern railway has used vast numbers of it in protecting their extensive piling in the bay at Everett, Wash.

TWO CENTURIES OF THOUGHT IN FILE PROTECTION

A Graphical Representation of Progress by Civil Engineers in Their Efforts to Kill and Prevent the Action of the Teredo and Limnoria.

Bent No. 1, showing unprotected piles in bridges, trestles, docks and wharves, and how they are eaten off by the Limnoria in from six months to several years.

Bent No. 2, showing unprotected piles entirely honeycombed by the teredo from the mud-line or bottom up to high water line in a period of from six months to several years.

Bent No. 3, showing creosoted piles attached as in bents No. 1 and No. 2—the speed of destruction only being slightly delayed.

Bent No. 4, showing pile with entire cylindrical surface between mud-line and high water, covered with large headed iron tacks. This method is ineffective and expensive—an obsolete Dutch preventive.

Bent No. 5, showing pile sheathed with sheet copper between some distance below mud-line and up above high water line. Very expensive and corrodes around nails. The teredo will enter a pile at an exposed surface no larger than a pin head.

Bent No. 6 shows piles wrapped with burlap soaked in tar. Note difficulties with burlap as piles penetrate below original mud-line, and the action of the teredo at a lower level later exposed owing to increased scour adjacent to pile. Also the weight of oysters and barnacles tears the burlap, weakened by the rotting effect of salt water. Thus the pile becomes exposed at various places.

Bent No. 7, showing concrete covering applied to pile after driving, using wood or removable steel forms placed by a diver. Concrete will adhere to the pile. Note, therefore, that as the increased scour lowers the mud-line around the pile, the wood becomes exposed at a most vital point—near the bottom, difficult to inspect. Moreover should this concrete covering become damaged, repairs are impossible. Note also that it is extremely difficult to apply concrete under water without weakening the mixture.

Bent No. 8, showing split vitrified clay pipe wired together and filled with concrete. Subject to same troubles as described in No. 7.

Bent No. 9, vitrified clay sewer pipe, strung over tops of piles and filled with sand. In a new structure these must be installed before deck is placed. In old structures caps must be removed before pipe can be placed. A serious objection is that repairs are impossible to one section of one pile without removing cap from bent.

Bent No. 10, showing Lock Joint concrete pipe, made in halves, placed AROUND a green pile and filled with sand. Joints are locked and sealed so tightly as to hold the finest sand; thus the pipe does not adhere to the pile but settles gradually and follows the mud-line, always keeping pile fully protected throughout the field of attack of these marine wood-borers. Obviously, this system can be applied to old structures as easily as to new, without removing deck, without interfering with traffic, and without the necessity of employing a diver and his expensive outfit. Inspection is a simple matter, since sand showing at the top guarantees sand in place down to the lowest mud-line. Thus the opportunity for the action of the wood-borer has been eliminated, as this system practically raises the mud-line above the water line.

Sectional View of Pile Destroyed
by Teredo.

Myakka River Bridge on Charlotte Harbor & Northern Railway in Southern Florida.
Length, ½ Mile Piles Protected with Lock Joint Pipe.

APPENDIX D.

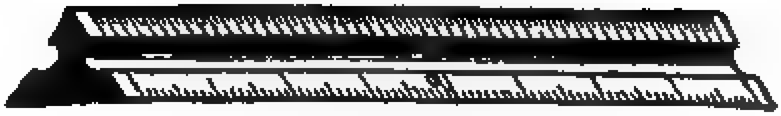
The illustrations which follow are supplemental to those shown in the text and are intended to show some of the instruments and devices used by civil engineers.

PRISMATIC COMPASS WITH THE CLYNOMETER ATTACHMENT

This is used to take the angle of slopes, and to take the magnetic bearings of a line. The Clynometer attachment is used to take the slope of the surface of the ground with a horizontal plane.

ANEROID BAROMETERS FOR MEASURING ALTITUDES.

By the use of this instrument the weight or pressure of the atmosphere is indicated by means of which the altitude above sea level is determined.



ENGINEER'S SCALE.
Divided into 10, 20, 30, 40, 50 and 60 Parts to the Inch.

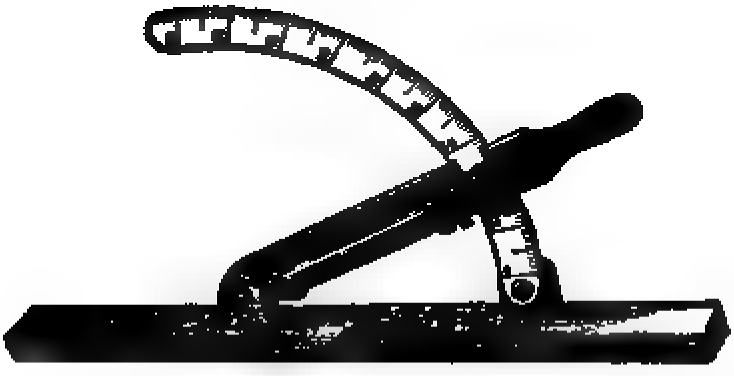
PROTRACTOR.

ENGINEER'S Y LEVEL.
For taking elevations and establishing benches.

ODOMETER.
For Recording Distance Covered by a Wheel.

ENGINEER'S STEEL TAPE.

CHESTERMAN'S METALLIC TAPE.



Clynometer or Slope Instrument.

LEVELING INSTRUMENT AND GRADIENTER.

Used for topographical work. Both elevations and distances can be taken by using this instrument.

Philadelphia Leveling Rod, with Target.

Light Mountain Transit, with Vertical Arc, Level on Telescope, and Clamp and Tangent to Telescope Axis, as Shown.

Used to take vertical and horizontal angles; also to extend straight lines. The level enables approximate elevations to be taken within limited distances. The vertical arc is used for taking vertical angles.

ENGINEER'S TRANSIT WITH LEVEL AND GRADIENTER ATTACHMENT.

The gradienter is for locating axis of the telescope on a grade line parallel with the grade of the proposed road; in connection with a level road is also used to measure distances.

PEDOMETER.

Placed in the pocket will record the distance the person carrying it has walked.

HAND LEVEL AND CLYNOMETER.

Used to ascertain points on same level as eye of observer. The Clynometer attachment is for taking the slope of the surface of the and with a horizontal plane.

APPENDIX E.

The following cuts of appliances and tools used in the construction and maintenance of track are supplementary to those shown in the text.

DRAG SCRAPER WITH RUNNERS.

DRAG SCRAPER WITH BOTTOM PLATE.

TWO-WHEELED SCRAPER.

SCRAPER (FOUR-WHEELED), READY TO LOAD FRONT PAN

SCRAPER (FOUR-WHEELED), THE REAR PAN DUMPED.

GRADER DITCHER AND WAGON LOADER.
Showing Side View.

A DUMP WAGON KNOWN AS A BOTTOM DUMP WAGON

Steam Shovel at Work.

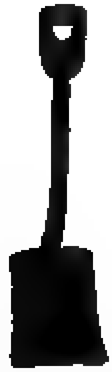
A GRADER DITCHER AND WAGON LOADER.
Showing Rear View of It.

AMERICAN RAILWAY-DITCHING MACHINE.

For cleaning and ditching mud cuts and scraping in dry cuts after plowed. Can be quickly moved out of the way of passing trains. Reversible, works either way without turning car or engine. Will scrape both ditches at the same time. The buckets are used in the same manner as an ordinary scraper.

Directions for using the American Railway Ditching machine.—If possible use an air-brake locomotive with this machine. See that slack between car and engine is well taken up, so as to prevent unnecessary jerking. Strengthen spring-hangers in the ordinary car, as the strain, at times, is quite severe. This result can be accomplished by putting in additional hangers. Use as small a wheel on car as possible; 20-inch wheels are the best size, although the ordinary flat car wheel will do the work.

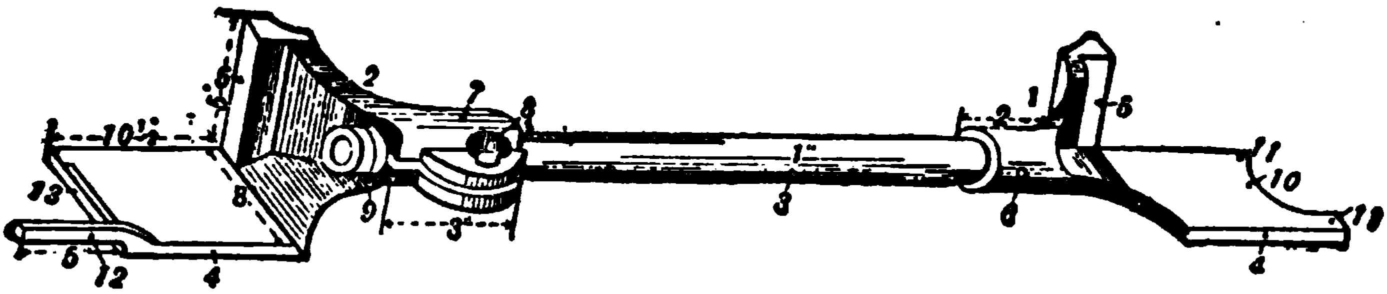
Track Saw.



RAILROAD SHOVEL.

For Tamping Earth, Sand and Some Varieties of Gravel Ballast and for Ditching, etc.

Rail Car



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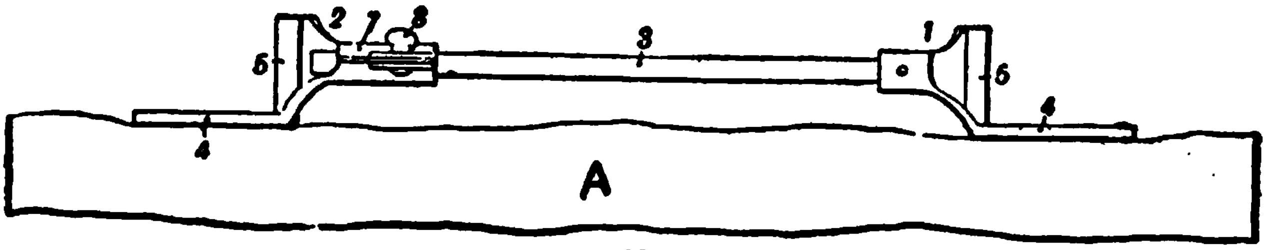

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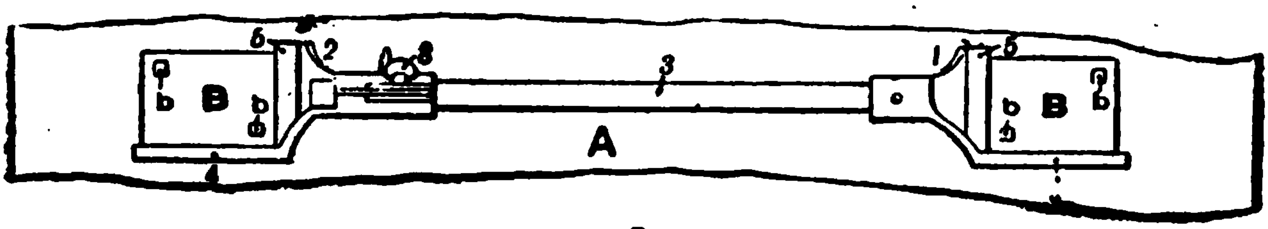

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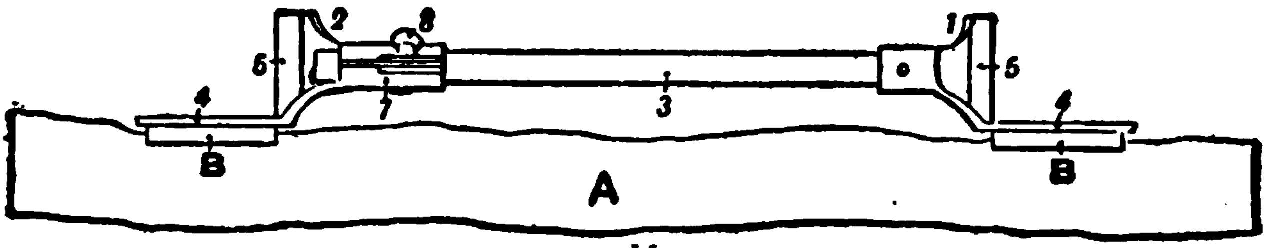
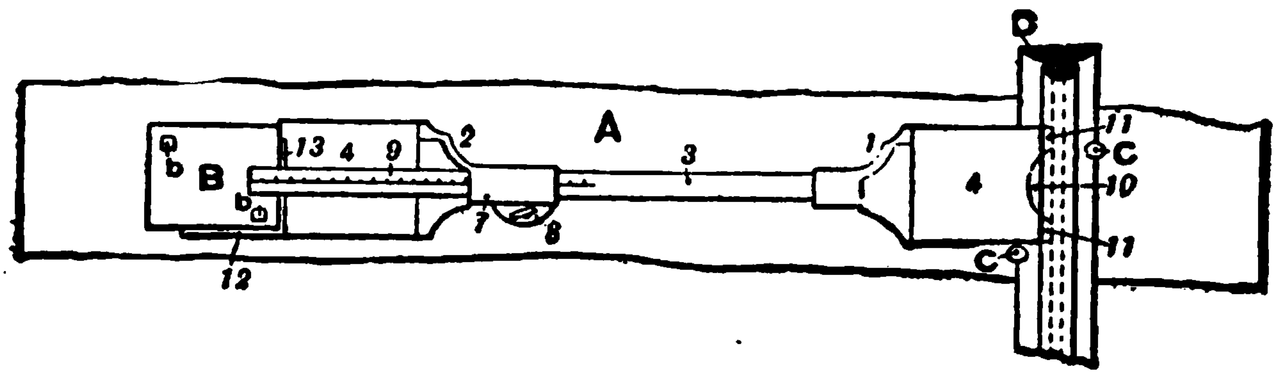


K



L

THE WARE TIE PLATE SURFACER AND GAUGE.

E, perspective of combined Tie Plate Surfacer and Gauge.

H, elevation of tool showing use on a tie to ascertain level at points where tie plates are to be embedded.

I, plan showing tool used to square and gauge tie plates.

K, elevation showing tool used for testing level of embedded tie plates.

L, plan showing implement used for gauging tie plates after ties are in track.

Track Lever or Lifting Bar, Used for Heavy Track Work.

A

B

A. Pinch Bar without a Heel.
B. Pinch Bar with a Heel.

Track Drill

Track Drill

Shows How a Rail-Brace Will Fail to Support the Rail Where It Cuts into the Tie, or the Rail-Brace Is Not Properly Designed

AMERICAN GUARD RAIL FASTENER.

Under the present conditions of heavy traffic, a reliable guard rail fastener is one of the essential requirements of a good track.

The guard rail brace, and base plate extending under both the guard rail and the rail of the main track, are thoroughly fastened together by rivets, and to further secure the brace three track spikes pass through both the brace and the base plate

Forged Steel Rail Braces.

A B

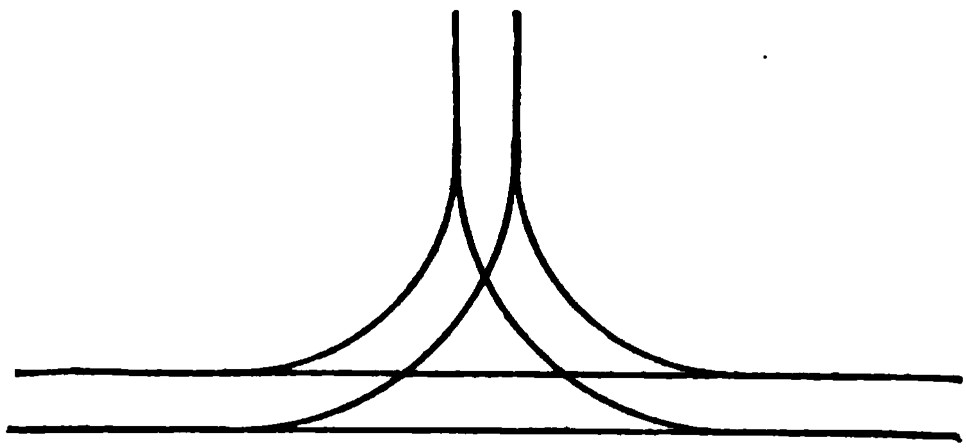
Bilge Pumps. A. Bottom Suction. B. Side Suction. For Pumping out Foundations.

APPENDIX F.

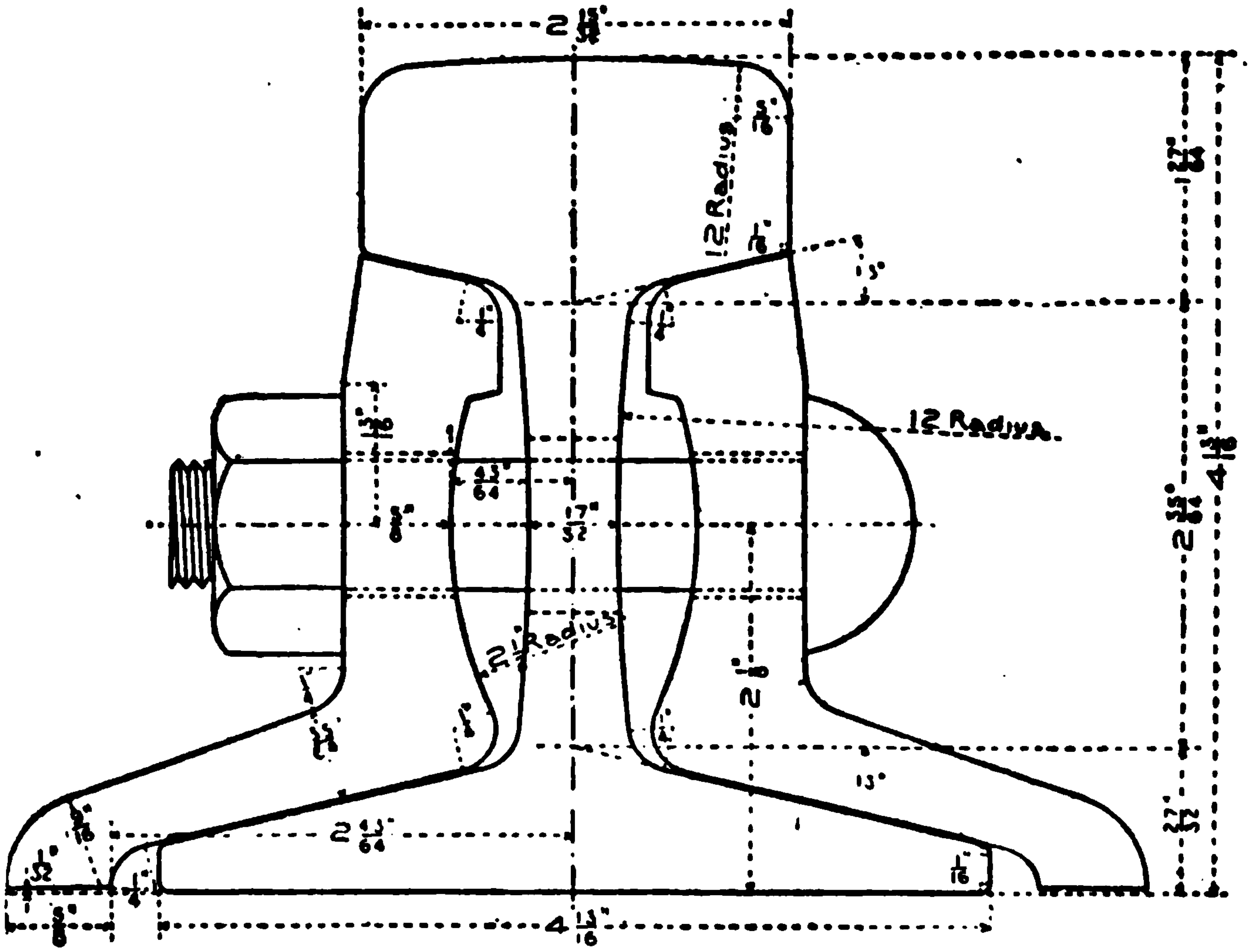
The cuts shown in this appendix are intended, through pictorial portrayal, to further illustrate methods described in the text of this volume.

Expansion of Rails in Varying Temperatures Should be Allowed for as Follows:

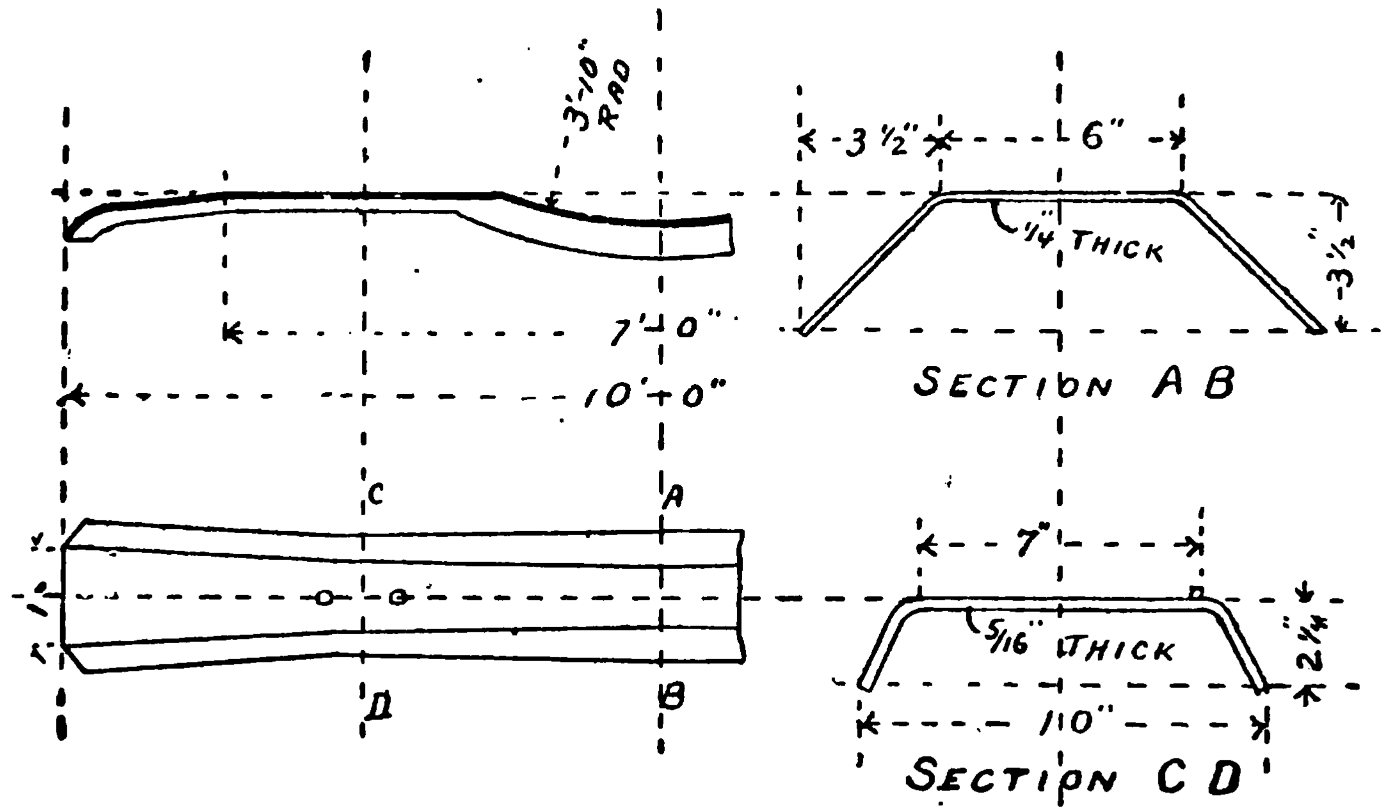
Thermometer	90 deg. or over, allow $\frac{1}{32}$	inch
"	70 to 90 deg., allow $\frac{1}{16}$	"
"	50 to 70 deg., allow $\frac{1}{8}$	"
"	30 to 50 deg., allow $\frac{3}{16}$	"
"	10 to 30 deg., allow $\frac{1}{4}$	"
"	10 ab. to 10 b'lw. allow $\frac{5}{16}$	"



Y Track, Usually Termed a (Why) "Y," Being Two Tracks Running from Main Line and Uniting in a "Y," Enabling Engines to Turn without a Turntable and for Purposes of Switching Cars or Trains.

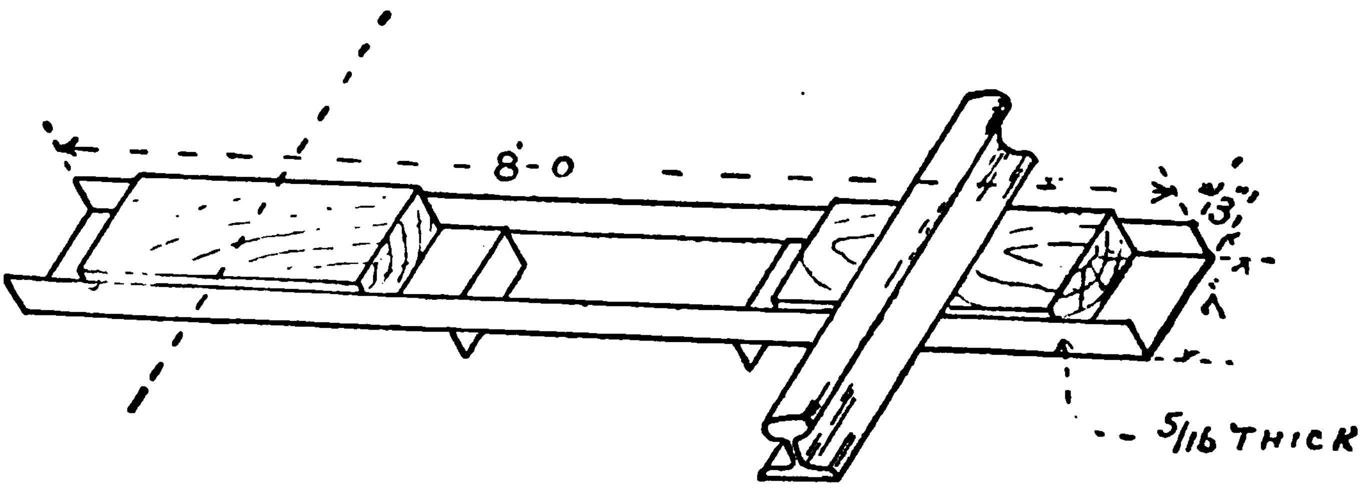


Angle Bars Used on a 75-lb. Rail of American Society of Civil Engineers' Standard.



METAL TIE.

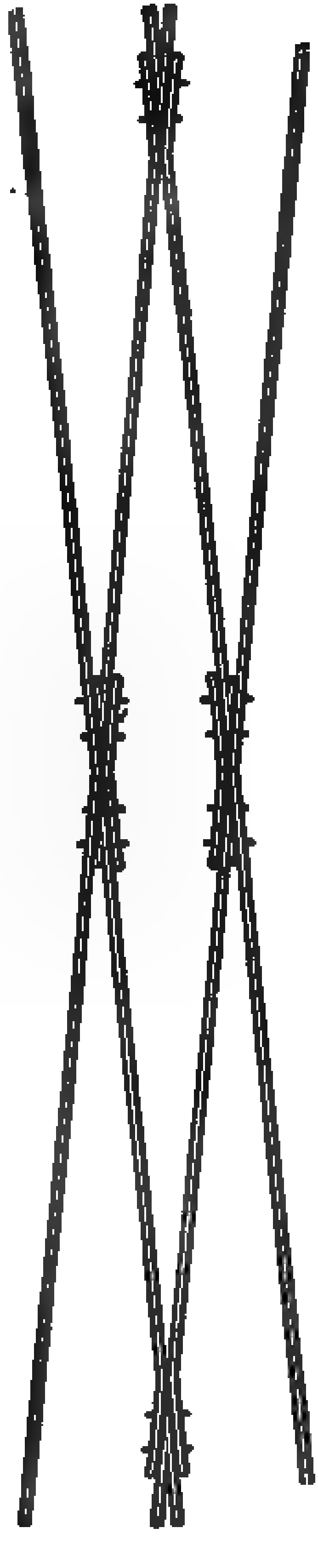
Used on the New York Central & Hudson River Railroad. Designed by Walter Katte, C. E.



MORRELL METAL TIE.

Used on Delaware, Lackawanna & Western Ry. The rail rests on a creosoted wooden block and the rail and block are securely bolted to the tie.

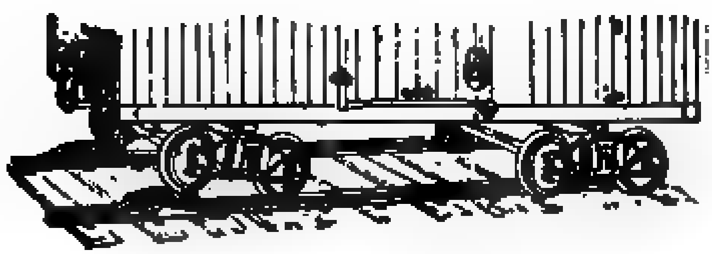
Double Slip Switch with Movable-Point Frog.



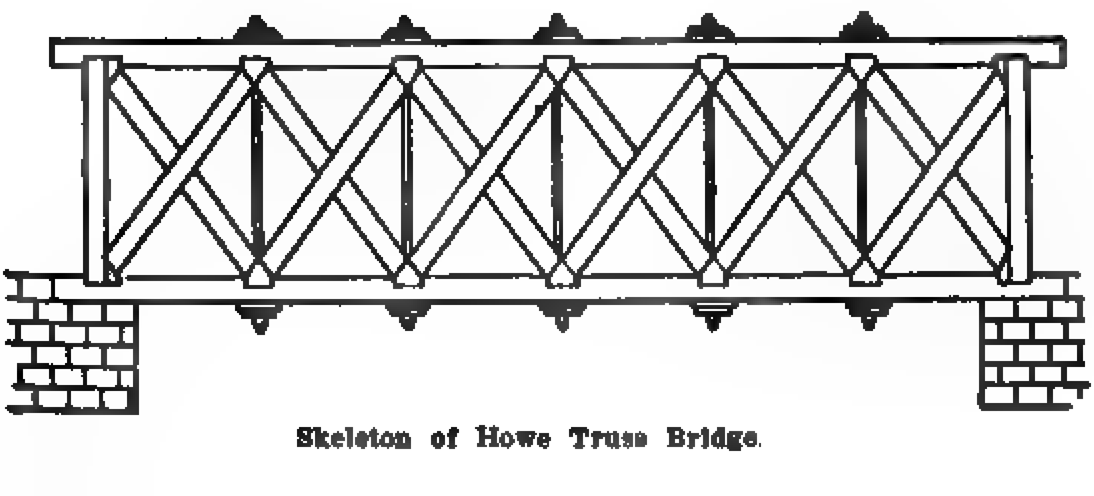
Crossing Frogs Used Where Two Tracks Cross at an Acute Angle.

Single Slip Switch with Rigid Middle Frogs.

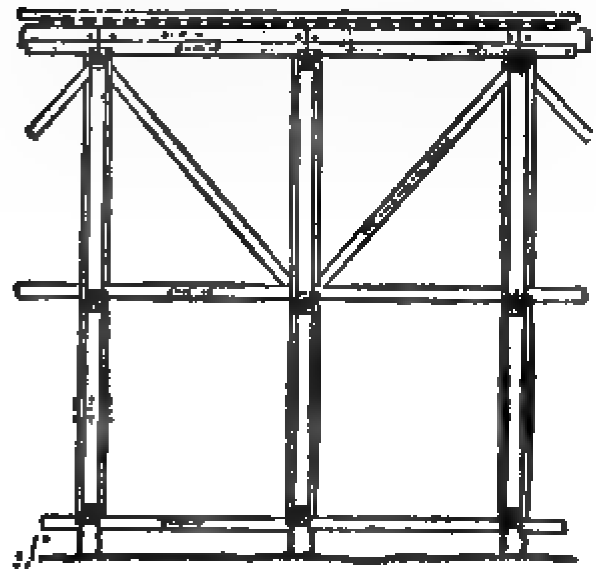
Replacer.



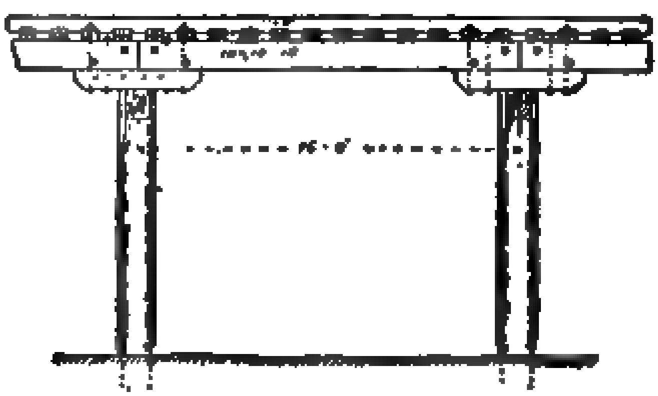
Car Replacing Device.



Skeleton of Howe Truss Bridge.



Framed Trestle.



Pile Trestle Bridge.

Temporary Trestle over a river, preparatory to building the bridge

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RAILWAY CONSTRUCTION—Continued.

RAILWAY CONSTRUCTION—Continued.

MAINTENANCE OF WAY—Continued.

BRIDGES AND BUILDINGS—Continued.

MISCELLANEOUS ILLUSTRATIONS—Continued.

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Successful Motorman

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Chicago, Ill.